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**SkyCast**<sup>®</sup>  
*Total Profiling System*

**Aviation Applications**

## Wind and Thermodynamic Profiling System (WTPS)

### Atmospheric Boundary Layer Profiling System

- Radar Wind Profiler
- Profiling Radiometer
- Acoustic Wind Profiler
- Data Integration
- Nowcasting Algorithms
- Display System

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## 1 Introduction

Radiometrics Corporation, based in Frederick, Colorado, USA, manufactures, installs, and maintains atmospheric remote sensing systems including:

- Temperature, humidity, and liquid water profiling radiometers (MPR)
- Radar wind profilers (RWP)
- Acoustic wind profilers (AWP)

Radiometrics pioneered the design of these instruments and with more than 460 profilers sold worldwide, is a recognized leader in state-of-the-science atmospheric profiling systems.

We are pleased to provide this briefing on our industry leading **SkyCast**<sup>®</sup> Wind and Thermodynamic Profiling System (WTPS), which is in use worldwide in a broad range of applications.

### 1.1 SkyCast

*SkyCast* is an integrated Wind and Thermodynamic Profiling System (WTPS).

A *SkyCast* system includes:

- Instrumentation
- Feature-rich Data Analysis
- Display
- Automated Alert Applications

*SkyCast* utilizes advanced atmospheric remote sensing technologies to provide continuous boundary layer measurements of wind, temperature, water vapor, and liquid profiles.

### 1.2 VizAir™

VizAir is a software suite developed for *SkyCast* providing cutting-edge nowcasting, and visualization tools for airport installations.

Radiometrics can configure *SkyCast* systems for a wide variety of applications including:

- Airport Safety Optimization
- Air Quality Monitoring
- Emergency Management
- Mesonet Enhancement
- Space Launch Support

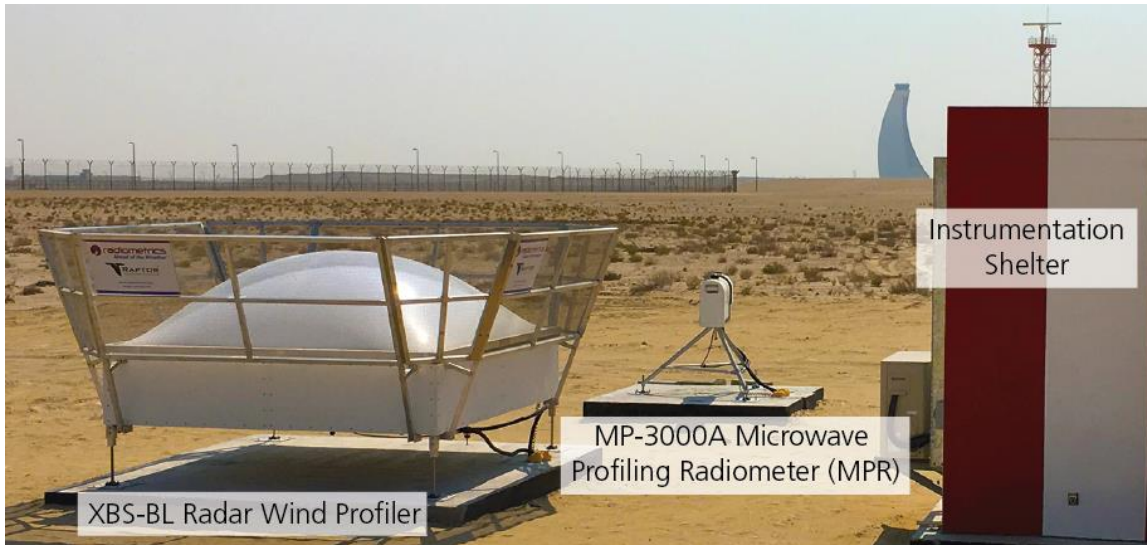


Figure 1 – SkyCast Installation Abu Dhabi International Airport (AUH)

SkyCast uniquely integrates remote observations from multiple instruments:

- RAPTOR® Radar Wind Profiler (RWP)
- MP-3000A Microwave Profiling Radiometer (MPR)
- Acoustic Wind Profilers (Sodars)
- Surface Weather Observing System

All data from collocated sensors are integrated and processed through VizAir software. VizAir is a web-based software suite that automatically generates and delivers critical nowcasting products along with a fully customizable alerting system.

VizAir provides weather forecasters and decision makers with up-to-date information during hazardous weather conditions and dynamic weather events that impact airport operations.

The SkyCast Wind and Thermodynamic Profiling System accurately provides hazardous weather alerts enhancing airport operational safety, reliability, and efficiency by providing state-of-the-science tools for timely alerts.

*The improved situational awareness for forecasters, pilots, and airport managers allows for safe, efficient, and successful airport operations, translating into airport cost savings.*

SkyCast LWDSS is a core component of an **Aviation Weather Decision Support System (AWDSS)** that includes Terminal Doppler Weather Radar (TDWR), integration with existing AWOS and LLWAS, and optionally numerical weather model data integration. Contact Radiometrics for additional information.

SkyCast operates at several high-traffic international airports including Dubai (DXB), Bangkok (BKK), Bahrain (BAH), and Abu Dhabi (AUH). There are a total of six SkyCast installations at international airports in Thailand, with three additional systems to be installed before the end of 2022. The Agency for Aerial Navigation Safety in Africa and Madagascar (ASECNA) has completed acceptance of the first of five SkyCast systems at

Nouakchott–Oumtounsy International Airport, with remaining systems scheduled for installation at airports in Chad, Burkina Faso, Niger, and Mali. Additionally, two SkyCast systems were recently installed at Elmendorf Air Force Base, Alaska.



Figure 2 – SkyCast with VAD-BL in Bangkok, Thailand (left); Mobile SkyCast at Elmendorf AFB, Alaska (right)

## 2 Airport Operations and SkyCast Relevance

SkyCast provides continuous, high temporal resolution profiles of atmospheric thermodynamic and wind conditions monitoring:

- Temperature, humidity, and liquid water content
- Atmospheric stability and convective forecast indices
- Temperature inversions
- Wind profiles and wind shear characteristics
- Evolution of the low-level jets
- Development and dissipation of fog events
- Presence of icing conditions

SkyCast provides key meteorological information within the Planetary Boundary Layer (PBL) from the surface to approximately 3000 m AGL<sup>1</sup>. The evolution and dynamics of PBL processes often drive the onset of mesoscale meteorological phenomena including high-impact weather events.

*The ability to monitor rapidly changing conditions in real-time is critical to forecasters in providing timely and effective support for airport and aircraft operations.*

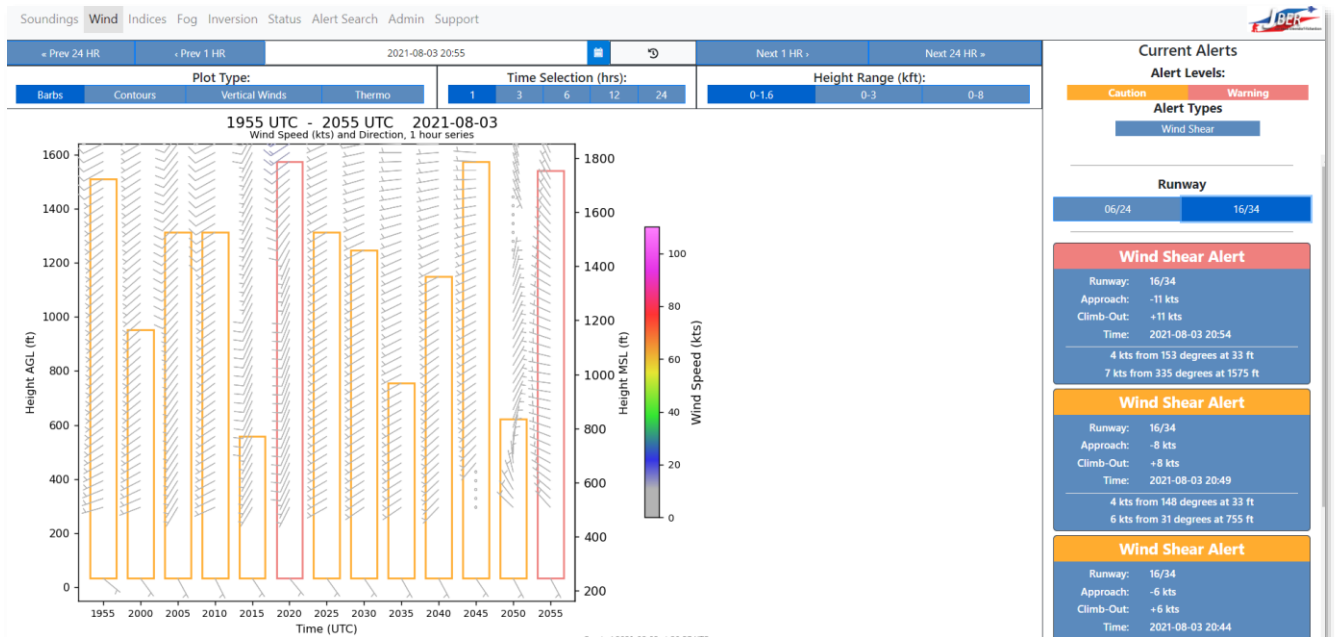
### 2.1 Terminal Area Wind Measurements

SkyCast provides the ability to constantly monitor low-level wind field characteristics along with any associated wind shear, low-level jets, headwinds, tailwinds, and crosswinds. These parameters are critical to pilot weather situational awareness and gauging aircraft performance. Wind retrievals are processed through

<sup>1</sup> Higher altitudes available in other system configurations; contact Radiometrics for details.

wind shear algorithms that derive shear magnitude and depth characteristics. Decision makers (like air traffic control and pilots) use these alerts to make informed decisions about takeoff and landing operations when wind shear conditions exist.

SkyCast shows wind shear alerts based on user definable shear thresholds (see Figure 3 and Figure 4). Shear alerts are defined using across or along runway values. By default, wind shear calculations and alerts are based on ICAO standards, summarized as headwind loss, tailwind and gain. Wind barb profiles and shear calculations are updated every 5-minutes.



**Figure 3 – VizAir Wind Barb Plot**

Low-level jets (LLJ) can significantly impact aircraft performance during landing and takeoff, both near the surface and aloft. As a result of LLJ timing, such events are troublesome for locations having considerable late evening and early morning flight operations.

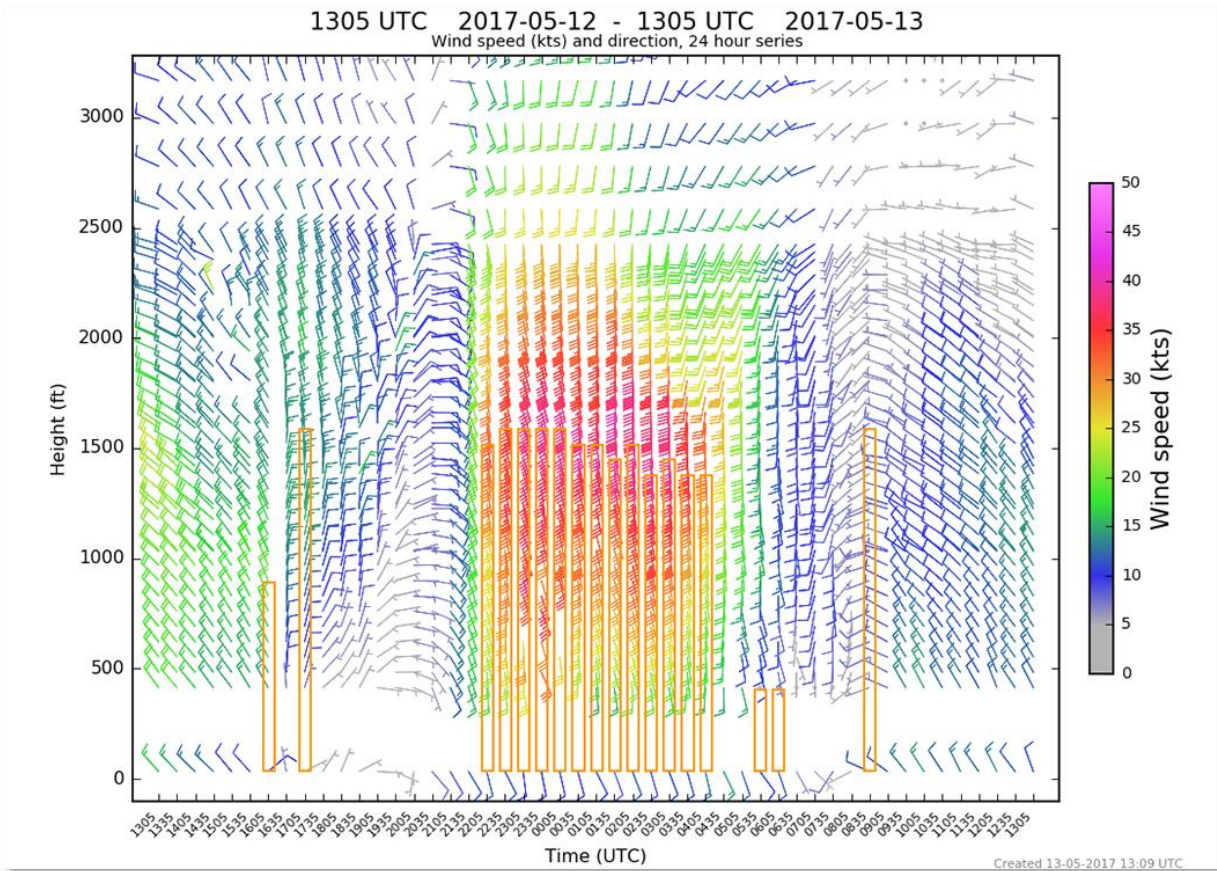
*SkyCast provides the ability to monitor the wind velocity and wind shear characteristics associated with LLJ in real-time.*

Mechanical processes often drive mixing of high velocity winds aloft down to the surface, resulting in an unforeseen increase in surface wind speeds. Atmospheric stability dictates downward mixing. Using radiometer retrievals provides forecasters with insight into mixing depth before mixing occurs.

If mixing depths extend to the surface and surface wind speeds significantly increase, local controllers may need to adjust runway configurations to avoid exceeding aircraft tailwind limits (resulting in inbound delays due to tactical rerouting).

Figure 4 shows a 24-hour time series of wind barbs and wind shear warnings from the Abu Dhabi SkyCast system.

**Note:** Strong LLJ (maximum winds > 45 kts) development just above the surface at approximately 2205 UTC, and the shallow depth of maximum LLJ speeds (less than 2000 ft in-depth).



**Figure 4 – Wind Shear Detection Overlays**

Wind profiles are updated every 5-minutes for closely monitoring the onset and dissipation of wind shear occurrences (like LLJ). Without this type of information, an airport forecaster cannot reliably predict LLJ onset, depth, or dissipation.

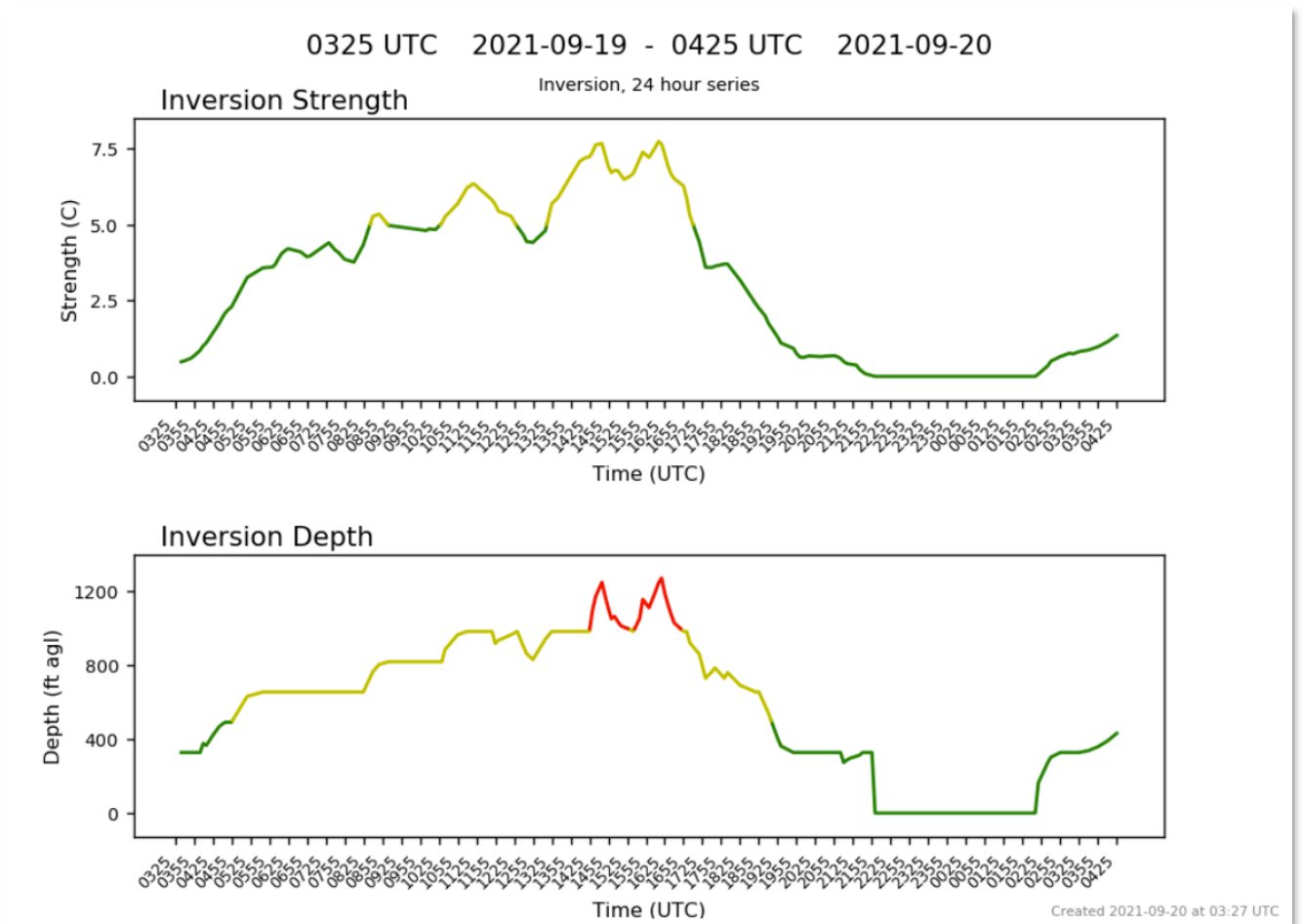
Strong shear and turbulence aloft may result in critical changes to aircraft performance, particularly during takeoff, and landing. Using wind shear detection overlays helps pilots make informed decisions regarding aircraft operation.

## 2.2 Temperature Inversions

SkyCast thermodynamic retrievals provide the ability to monitor low-level temperature inversions (LLTI) that effectively change the atmospheric density profile. Upon takeoff, fully loaded aircraft encountering a LLTI may experience a decrease in climb rate for the same thrust rate as compared to a takeoff where the LLTI is not present.

Using real-time LLTI information from SkyCast, air traffic controllers can alert pilots of the potential for lower-than-expected climb rates. ATC personnel can also establish climb-out protocols based on SkyCast atmospheric profiles to improve operational safety and provide fuel savings.

An example of inversion tracking is shown in Figure 5. Shown is a 24-hour time period of 5-minute updates when an inversion developed with a maximum strength of approximately 7.5° C and depth of ~1200 ft AGL. The traces are color coded according to user defined settings.



**Figure 5 – Temperature Inversion Trace**

### 2.3 Terminal Area Fog Conditions

*SkyCast* provides real-time observations of water vapor and liquid water in the PBL. This information, combined with temperature, dewpoint, and relative humidity, forms the basis for fog detection and characterization, a major contributor to airport delays. Studies using WTPS instrumentation show conditions associated with the evolution of fog events are dependent on the type of fog, as well as on mesoscale and geographic features specific to the location. As such, formation and dissipation characteristics need to be analyzed at the installation site to adapt *SkyCast* algorithms for the nuances specific to the location.

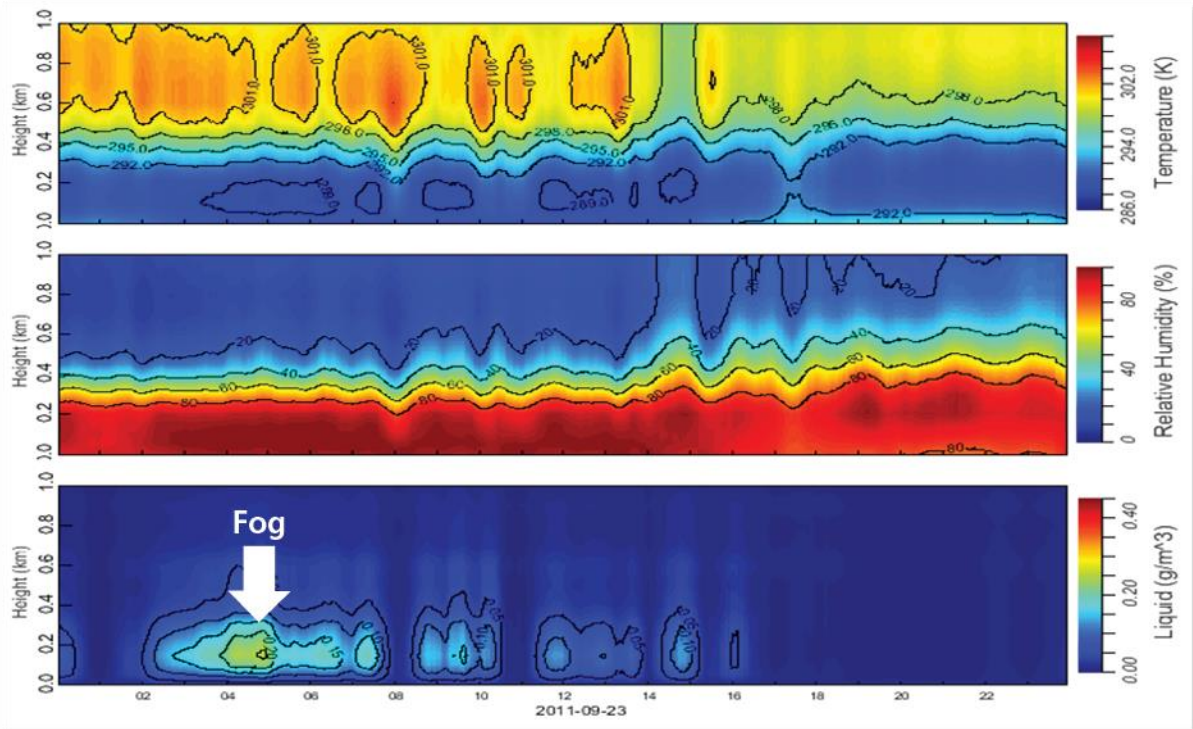
Forecasters at Dubai International Airport (DXB) successfully showed that additional information from *SkyCast* in-situ observations significantly increased understanding the local PBL structure during fog events improving predictability.

For example, DXB meteorologists used WTPS observations to verify that high humidity in the PBL was in excess of 1,000 ft deep, inhibiting fog formation. Under these conditions radiative cooling cannot provide enough heat loss to cool the atmosphere sufficiently to reach saturation during the overnight hours. Additionally, cooling at the top of the PBL often leads to stratus cloud development, further limiting the amount of longwave radiation that escapes the PBL.



The SkyCast humidity and liquid profiles displays, shown in Figure 6, clearly indicate fog conditions. In this example from Los Angeles International Airport, the VizMet display show the buildup of water at approximately 150 m AGL starting at 0200, with fog occurring at approximately 0400.

*Local forecasters recognize when fog conditions are present and successfully provide a confident no fog forecast, even though the numerical weather prediction models suggest fog formation in the terminal area is likely.*



**Figure 6 – Temperature, Relative Humidity, Vapor Density, Fog, and Winds**

Figure 7 shows an example of fog algorithm output based on SkyCast data over a 12-hour period, in this case the fog index developed by the US Air Force. Such algorithms are tuned to local environments as cases are collected and verified.

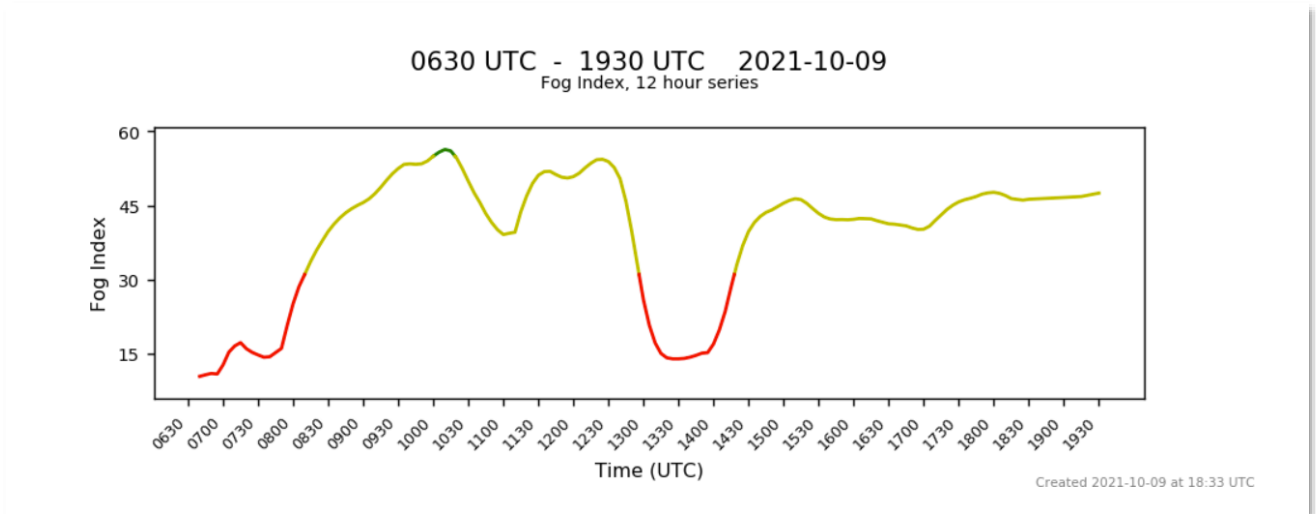


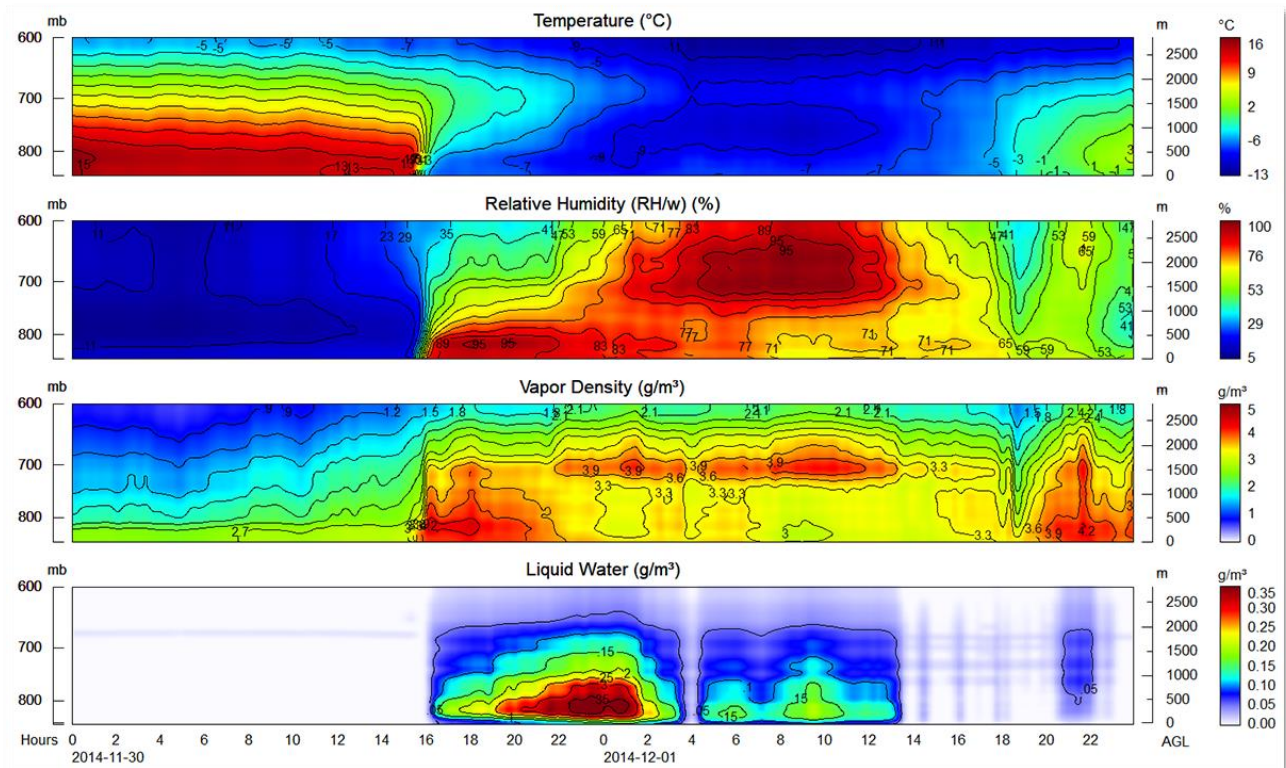
Figure 7 – Fog Index Output for 12 Hour Period

## 2.4 Terminal Area Frost, Freezing Rain, and Icing Conditions

SkyCast provides measurements of integrated vapor and liquid throughout the atmosphere. These measurements, when combined with the retrieved temperature profiles, allow for the monitoring of potentially hazardous phenomena including frost, freezing rain, and icing.

*When potentially hazardous precipitation events occur, SkyCast provides continuous monitoring of PBL temperature, liquid water, and vapor density profiles. This information is vital to determining precipitation type and amount at the surface. SkyCast helps discriminate between rain, freezing rain, ice pellets, and snow. Real-time temperature profiles assist in forecasting the timing of any precipitation phase changes.*

The ability to monitor and nowcast changes in real-time allows for informed decisions resulting in significant improvements to operational procedures and expenses, including improvements to the scheduling and efficiency of deicing operations. A SkyCast airport display identifying icing hazard is shown in Figure 8.



**Figure 8 – Dense Drizzle and Fog – Severe Icing**

SkyCast provides real-time monitoring of atmospheric thermodynamic and wind conditions, along with traditional sounding forecast indices. Forecasters utilize this information to derive stability parameters, and to reliably monitor potential for severe weather. By tracking dynamic conditions in real-time, forecasters have valuable information on the potential storm type and severity characteristics, as well as the timing of convective initiation. In contrast, radiosondes are launched from a small number of sites globally two times per day at 00 UTC and 12 UTC to monitor atmospheric conditions. Unfortunately, very few PBL observations exist between the two launch times when much of the dynamic weather occurs.

*SkyCast provides continuous intermediate soundings through remotely sensed observations at a temporal resolution of approximately 5-minutes, giving meteorologists a nowcasting tool for monitoring the convective initiation and the associated characteristics.*

A SkyCast sounding analysis and display with forecast indices and thermodynamics is shown in Figure 9.

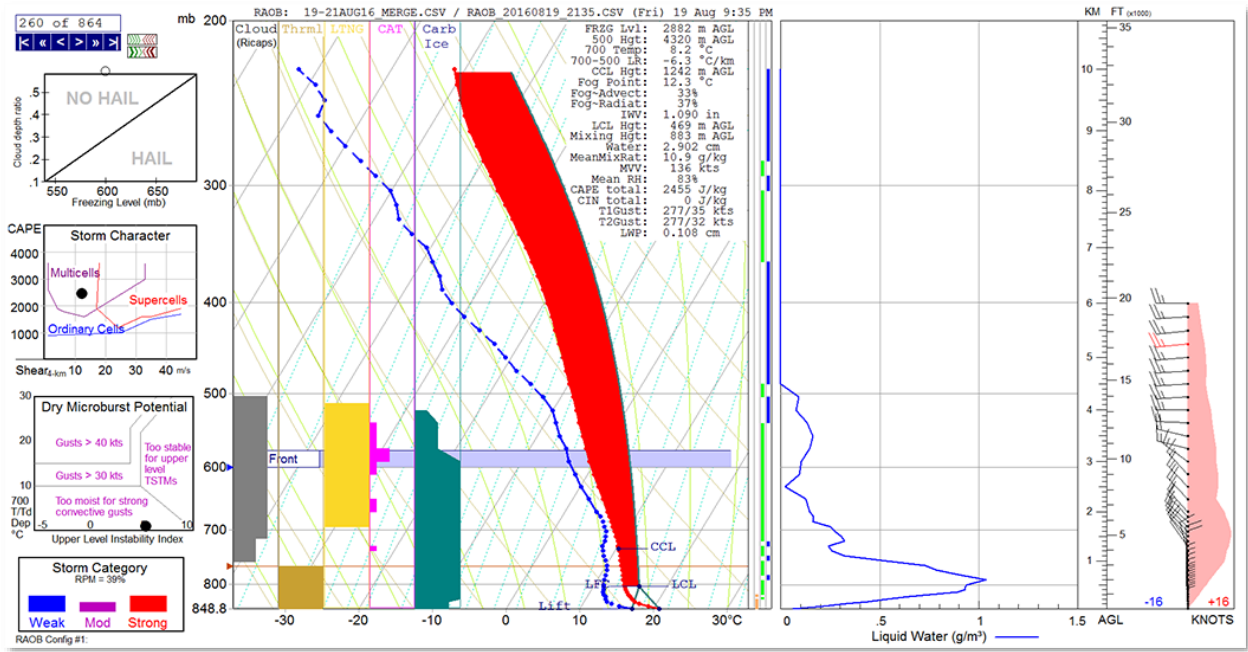


Figure 9 – Sounding with Indices, Thermodynamic, and Storm Characteristics

Figure 10 shows a time series of surface (SFC), mixed-layer (ML) Convective Available Potential Energy (CAPE), and Convective Inhibition (CIN) calculated from the SkyCast data every 5-minutes. The first hour of the plot is observations while the second hour of the plot is a nowcast trend. The time series are color coded by user defined thresholds. These plot types give forecasters information from which to confidentially base times of potential convective initiation and severity.

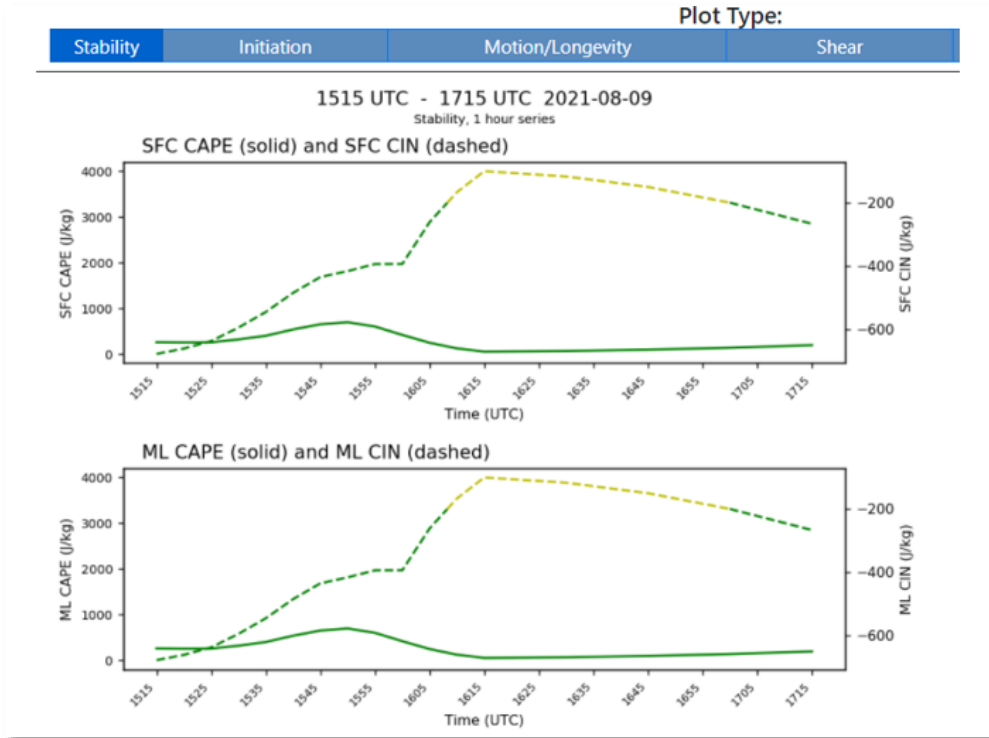


Figure 10 – Stability Trace Examples

### 3 Remote Sensing Instrumentation

The following remote sensing instrumentation are delivered as part of the *SkyCast* system:

- MP-3000A Microwave Thermodynamic Profiling Radiometer (MPR)** provides continuous real-time vertical retrievals of temperature, humidity, and liquid water from the surface to 10 km. *SkyCast* utilizes full profiles to derive traditional forecast indices, while leveraging the profiler’s inherent strength in low levels for high-resolution boundary layer analyzes. Hallmarked by high reliability (MTBF > 40,000 hours) and proven profiling accuracy, there are over 340 MP-3000A instruments in operation worldwide.
- RAPTOR Boundary Layer Radar Wind Profiler (RWP)** accurately measures wind speed and direction up to 3 km AGL or higher, depending on atmospheric conditions, and RWP model. For northern latitudes, dry climates, or locations where winds above the PBL are desired, higher-power RAPTOR options are available from Radiometrics.
- Acoustic Wind Profiler (Sodar)** provides high-resolution wind observations from near-surface to 200 m AGL (optionally up to 700 m). High vertical resolution winds from the sodar combined with surface observations are used to bridge the gap between the surface and the lowest RWP observation. Sodars produces wind measurements by emitting a strong acoustic pulse in the audio band and detecting the Doppler frequency shift of the received backscattered echo. Data from the sodars is integrated with other instrumentation datasets to provide high-resolution wind profiles between the surface and first measurement gate of the RWP. Sodar data is updated every 5-minutes.

- **Automatic Weather Station (AWS)** can be provided with *SkyCast* installations when local Automated Weather Observation System (AWOS) data is not available.

## 4 Analysis and Visualization Software Suite

The *SkyCast* system analysis and visualization software includes:

- **VizAir Launchpad** is a dashboard that displays user alerts and provides easy access to additional applications.
- **Integrated Wind Shear Alerting System** is an algorithm and alerting suite that detects wind shears measured by the RWP according to FAA or ICAO requirements for non-convective wind shear, and alerts based on user defined alerting thresholds.
- **Fog Detection and Trending System** is an algorithm and alerting suite detecting fog. It analyzes trend information for burn off rate estimates.
- **Inversion Detection and Trending System** is an algorithm and alerting suite detecting inversions. It analyzes trend information to estimate dissipation times.
- **Nowcast Product Generator** is software responsible for data integration, database generation, algorithmic processing, data archiving, and playback.
- **VizAir Display** is visualization software for examining integrated data and evaluating alerts.
- **Sounding Toolkit** software provides visualization and comprehensive interrogation of sounding data using the Universal Rawinsonde Observation (RAOB) program.
- **VizMet-Pro** is the MPR control interface and provides basic visualization displays. VizMet-Pro now includes proprietary ACal automated calibration methods, and is the only profiling radiometer system that does not require routine liquid nitrogen calibration.
- **BIRCH™** is the control interface providing RWP health and status monitoring.
- **ASPEN™** is the RWP signal processing and data display system.
- **SkyCast Status Page** provides a status overview of hardware and processing components, shelter environmental conditions, and file latency information.

All data processing is performed by the central processing unit, typically installed inside an electronics shelter located near the SkyCast instrumentation. Results of data processing are transmitted to the Forecast Office as shown in Figure 11. Optionally, wind shear warnings can be provided to the ATC tower.

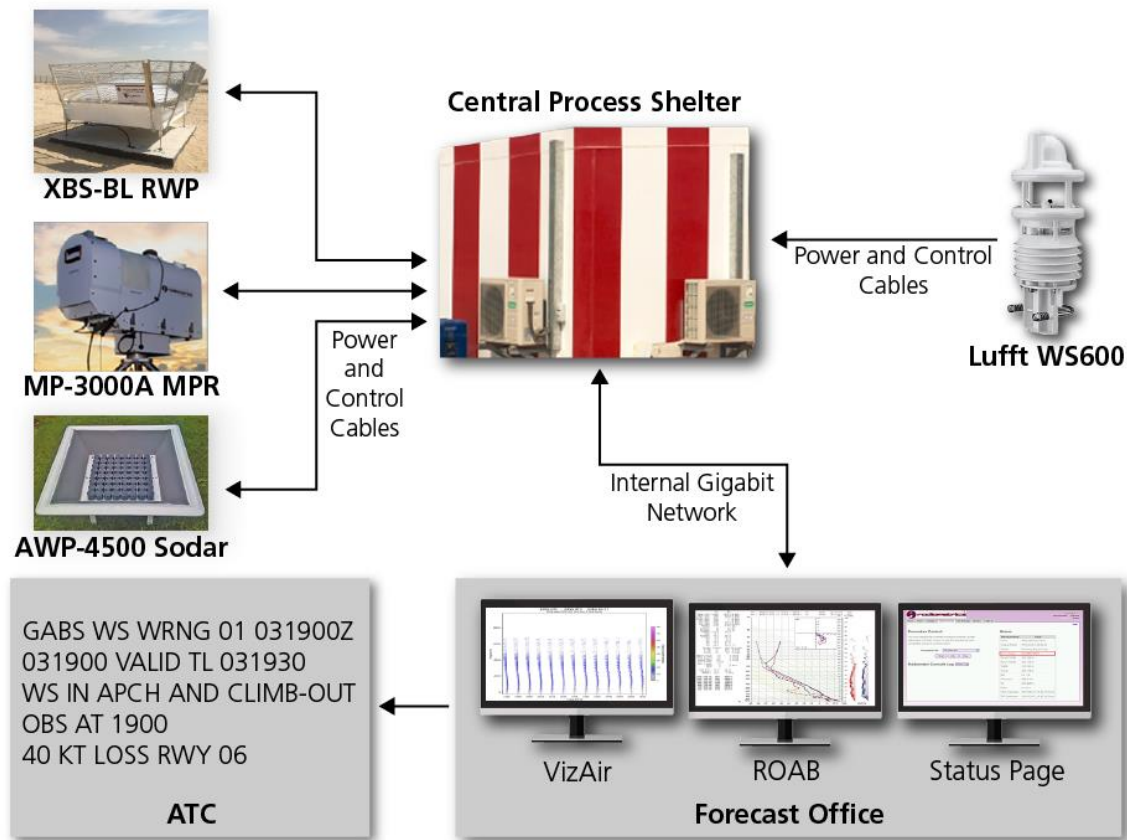


Figure 11 – SkyCast System Configuration

## 5 SkyCast Data Integration, Processing, and Visualization

A SkyCast installation includes all hardware and software necessary to integrate data retrievals from all instrumentation. It processes the integrated data through proprietary algorithms, and displays the products for visualization and analysis. The VizAir display is provided by a web page viewed by any number of users and from any location that has access to the VizAir URL.

Figure 12 shows an example of the VizAir display front page. The selection bar across the top of the page allows the user access to the various VizAir functionality. In addition to providing access to real-time data and products, the system allows access to several months of archive for accessing previously produced data and products.

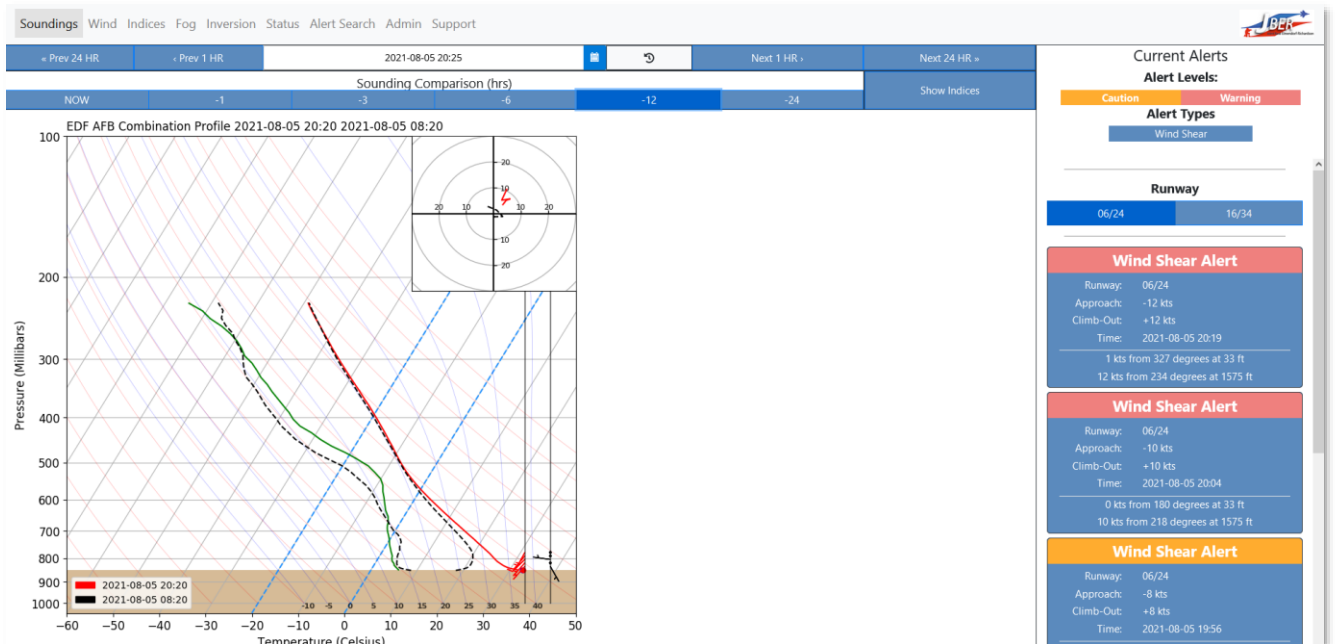


Figure 12 – VizAir Display Front Page

The RAOB Sounding Toolkit allows for in-depth interrogation of all aspects of sounding data. Figure 13 shows a sounding example in RAOB. This package provides the ability to generate many forecast indices, as well as manually manipulating the soundings to more readily assess the impacts on future atmospheric conditions.

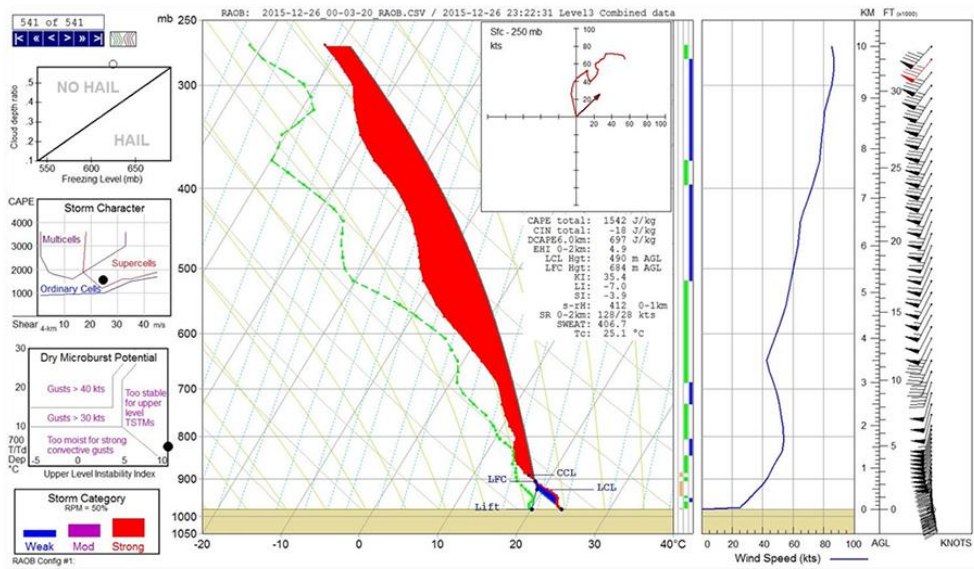


Figure 13 – RAOB Integrated Sounding



## 6 Integrated Wind Shear Alerting System

SkyCast wind profilers when combined with surface observations, provides continuous vertical profiles of wind characteristics within the boundary layer from the surface to approximately 3 km. As such, the high-resolution data is ideal for determining the vertical shear of the horizontal wind. The Integrated Wind Shear Alerting System (IWAS) ingests wind profiler, sodar, and surface station data. IWAS then processes data through a detection algorithm to isolate regions of vertical shear of the horizontal wind according to the ICAO manual on Low-Level Wind Shear.

Wind shear is calculated in the lowest 500 m (1600 ft) and expressed as kts/100 ft or km/h per 30 m. IWAS also takes runway orientation into account to determine headwind loss and tailwind gain during takeoff and landing.

Figure 14 shows an example of the IWAS display. Display components include:

- Graphical and numerical information showing current wind shear alerts
- Graphical and numerical wind velocity output for all profiler levels
- Panels showing output for varying time periods and vertical depths
- Color coded wind barbs based on wind speed
- Color coded alerts that outline regions of vertical wind shear
- Ability to analyze archived plots and alerts

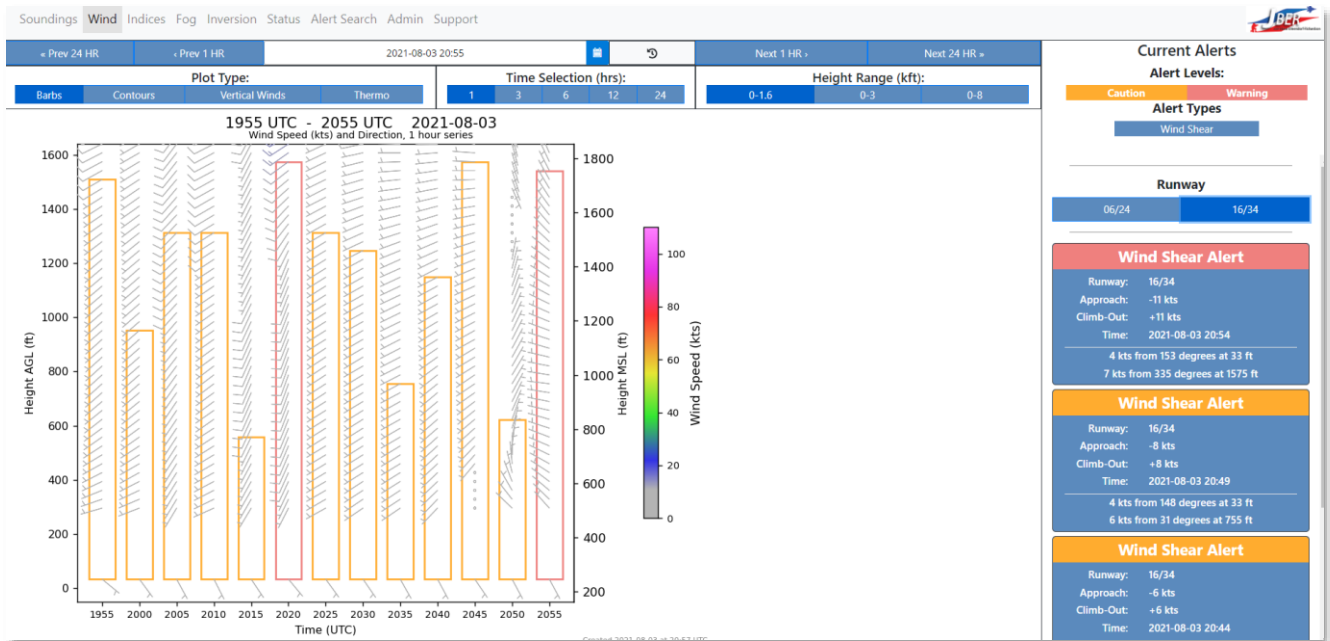
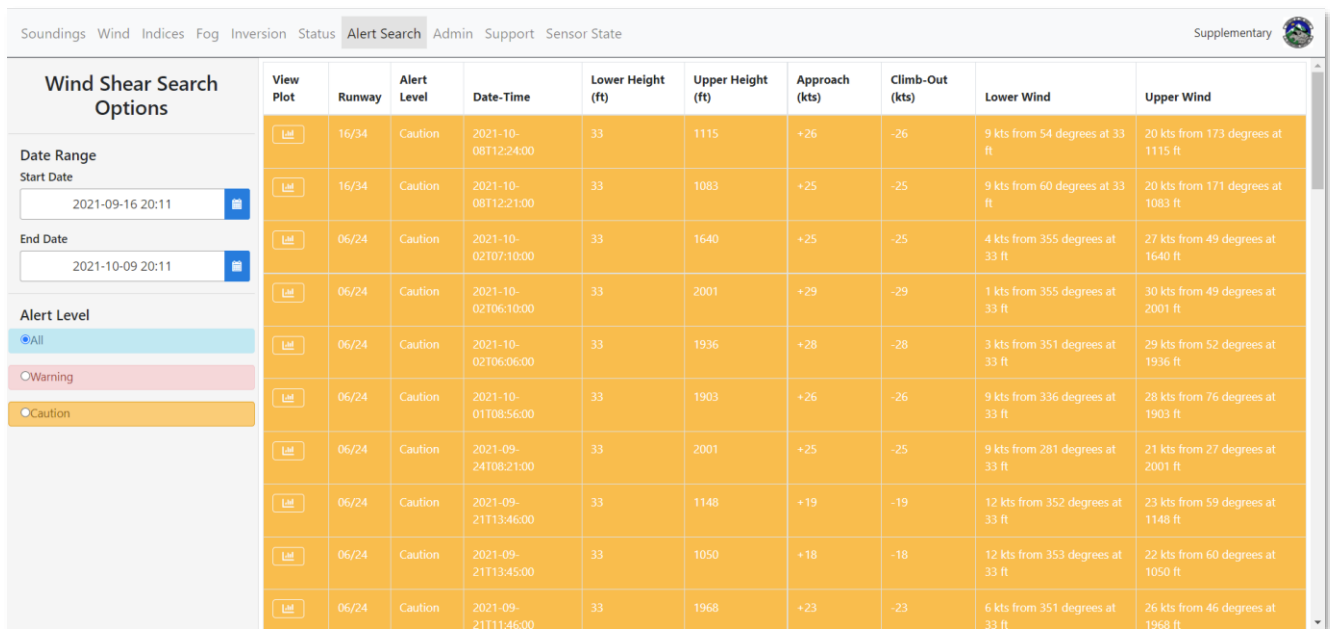


Figure 14 – Integrated Wind Shear Alerting System (IWAS)

Messages regarding wind shear are put into standard formats according to requirements as outlined in ICAO International Standards and Recommended Practices, Annex 3 that can be sent to the ATC tower, or other users. The following is an example:

```
GABS WS WRNG 01 031900Z VALID TL 031930Z
WS IN APCH AND CLIMB-OUT
WS DUE TO LOW-LEVEL JET
OBS AT 1900
40 KT LOSS RWY 06
```

Figure 15 shows an example of the Alert Search page. Users can review past data plots and wind shear alerts. Search criteria include type, date range, and alert severity.



Wind Shear Search Options		View Plot	Runway	Alert Level	Date-Time	Lower Height (ft)	Upper Height (ft)	Approach (kts)	Climb-Out (kts)	Lower Wind	Upper Wind
Date Range			16/34	Caution	2021-10-08T12:24:00	33	1115	+26	-26	9 kts from 54 degrees at 33 ft	20 kts from 173 degrees at 1115 ft
Start Date 2021-09-16 20:11			16/34	Caution	2021-10-08T12:21:00	33	1083	+25	-25	9 kts from 60 degrees at 33 ft	20 kts from 171 degrees at 1083 ft
End Date 2021-10-09 20:11			06/24	Caution	2021-10-02T07:10:00	33	1640	+25	-25	4 kts from 355 degrees at 33 ft	27 kts from 49 degrees at 1640 ft
Alert Level			06/24	Caution	2021-10-02T06:10:00	33	2001	+29	-29	1 kts from 355 degrees at 33 ft	30 kts from 49 degrees at 2001 ft
<input checked="" type="radio"/> All			06/24	Caution	2021-10-02T06:06:00	33	1936	+28	-28	3 kts from 351 degrees at 33 ft	29 kts from 52 degrees at 1936 ft
<input type="radio"/> Warning			06/24	Caution	2021-10-01T08:56:00	33	1903	+26	-26	9 kts from 336 degrees at 33 ft	28 kts from 76 degrees at 1903 ft
<input type="radio"/> Caution			06/24	Caution	2021-09-24T08:21:00	33	2001	+25	-25	9 kts from 281 degrees at 33 ft	21 kts from 27 degrees at 2001 ft
			06/24	Caution	2021-09-21T13:46:00	33	1148	+19	-19	12 kts from 352 degrees at 33 ft	23 kts from 59 degrees at 1148 ft
			06/24	Caution	2021-09-21T13:45:00	33	1050	+18	-18	12 kts from 353 degrees at 33 ft	22 kts from 60 degrees at 1050 ft
			06/24	Caution	2021-09-21T11:46:00	33	1968	+23	-23	6 kts from 351 degrees at 33 ft	26 kts from 46 degrees at 1968 ft

Figure 15 – Alert Search Function

## 7 Conclusion

SkyCast is an integrated state-of-the-science atmospheric remote sensing solution, using proven technology, and easy-to-use decision support tools. SkyCast provides forecasters with continuous real-time monitoring of atmospheric boundary layer conditions, along with automated analyses, and alerting for local high-impact hazardous weather conditions affecting airport operations. SkyCast systems are currently operating at international airports, and new systems are under construction or under contract at commercial airports.

The Radiometrics team of engineers, field technicians, meteorologists, and atmospheric scientists ensure our customers receive detailed theoretical and application specific training, along with exceptional post installation support.

Contact Radiometrics to discuss how SkyCast can solve your mission critical forecasting and alerting needs.

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