4.7

AN AVIATION WEATHER DECISION SUPPORT SYSTEM (AWDSS) FOR THE DUBAI INTERNATIONAL AIRPORT

*Charles A. Barrere, Jr., M. Eilts, J. Johnson, R. Fritchie, P. Spencer, B. Shaw, Y. Li, W. Ladwig, R. Schudalla, and D. Mitchell

Weather Decision Technologies, Inc.
Norman, Oklahoma

1. INTRODUCTION

Weather Decision Technologies, Inc. (WDT) has developed and deployed a custom Aviation Weather Decision Support System (AWDSS) to support operations at the Dubai International Airport and the Dubai World Central International Airport at Jebel Ali (currently under construction) in the United Arab Emirates. The Dubai International Airport is affected by thunderstorms roughly 10 days per year, by fog during 4 months per year, and by sea breeze fronts and strong temperature inversions (with associated wind shear and turbulence) quite often. These weather phenomena can greatly impact operations at the airport. Thus, having the ability to detect, nowcast, and forecast these phenomena precisely and accurately has immense value. Providing that information to both the meteorologists and air traffic controllers, in a manner they can use operationally, is also of great importance.

The AWDSS collects meteorological data from several sources, integrates the data, runs a suite of detection and nowcasting algorithms, incorporates a Weather Research and Forecast Model (Shaw et al. 2008), and provides end-user interfaces (Figure 1) for real-time air traffic control operations as well as the support of operational meteorologist's work flow.

The system was installed and commissioned in December 2007 and is currently undergoing a "tuning phase" by which each algorithm's performance will be carefully evaluated and tuned based on the unique environmental conditions present in the UAE.

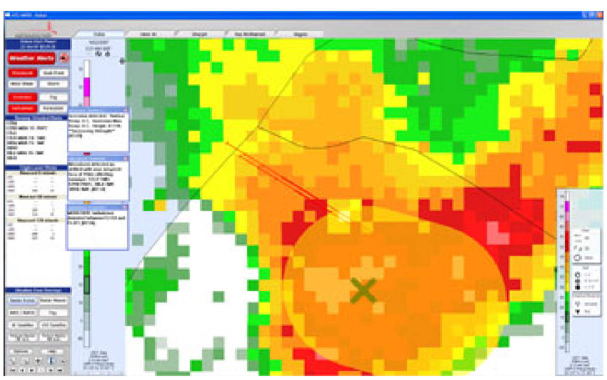

Figure 1 The AWDSS Display Showing a Microburst Affecting the Dubai International Airport

* Corresponding author address: Charles Barrere, Weather Decision Technologies, 3100 Monitor Ave. Suite 280 Norman, OK 73072; e-mail: cbarrere@wdtinc.com

2. DATA SOURCES

WDT's AWDSS utilizes real-time meteorological data from a C-Band weather surveillance radar, vertical profiles of temperature, humidity, and liquid water from a Radiometrics radiometer, vertical profiles of wind velocity from a Degreane wind profiler, surface observations, satellite data, and UAE radar mosaics.

2.1. *C-Band Weather Surveillance Radar*

In 2001, Enterprise Electronics Corporation (EEC) installed a C-Band weather surveillance radar at the Dubai International Airport. This radar became an integral part of the design of the AWDSS, mainly to support the automated detection of aviation-related hazards such as microbursts and gust fronts. A volumetric scanning strategy is utilized which provides data beam-by-beam through eleven tilts every five minutes.

2.2. *Temperature, Humidity, and Liquid Water Profiling Radiometer*

The Radiometrics MP-3000A Microwave Profiler (Figure 2) is a rugged hyper-spectral microwave radiometer that provides continuous vertical profiles of temperature, humidity, and liquid water. These profiles extend from the surface up to 10 km in height. The MP-3000A observes up to 21 K-band (22 to 30 GHz) and 14 V-band (51 to 59 GHz) microwave frequency channels and one 10 micron infrared channel.

Figure 2 Radiometrics MP-3000A Radiometer

2.3. *Wind Profiling Radar*

The Degreane PCL-1300 (Figure 3) is a pulsed Doppler radar which uses refractive index fluctuations of the air, mainly created by turbulence, as a tracer. These wind borne variations backscatter part of the transmitted energy. In the lower troposphere, the refractive index in-homogeneities are mainly produced by humidity fluctuations. Three antennae are arranged in a fashion to measure the U, V, and W Doppler components. These components are used to compute both the vertical and horizontal wind components. The radar operates at 1290 MHz and has a peak power of 3500 Watts. It generates vertical wind profiles up to 5 km in height, depending upon atmospheric conditions. The PCL-1300 operates in two modes, high mode and low mode, with a maximum gate spacing of 375 and a minimum of 75 m respectively, depending on which mode is being utilized.

Figure 3 PCL-1300 Wind Profiler

2.4. *Surface Observations*

The standard set of WMO METAR surface observations is provided to the AWDSS via an IBL meteorological data switch. These observations are decoded and stored in a database for use by the AWDSS. Additionally, a collection of surface observation stations are maintained by the government of the UAE. These observations augment the METAR data by providing additional data from stations over the Persian Gulf and the UAE. Finally, a local AWOS network provides high resolution surface observation data from stations located near the airport runways and surrounding areas in close proximity to the Dubai International Airport.

2.5. *High Resolution Satellite Data*

Meteosat Second Generation (MSG) geostationary meteorological satellite data are being ingested by hardware previously installed in the Dubai Met office at the Dubai International Airport. The MSG satellite data are available in various infrared and visible wavelength channels, and the data are updated every 15 minutes. The 10-bit MSG data are then ingested by the AWDSS system for use by several algorithms.

2.6. *UAE Radar Mosaics*

An installation of the TITAN (Thunderstorm Identification Tracking Analysis and Nowcasting, Dixon and Weiner 1993) system was implemented at the Dubai International Airport by UCAR in 2001. The radar data from the EEC radar in Dubai along with several other radars around the UAE are sent to a central location in Abu Dhabi where a mosaic is created by a multiple radar installation of TITAN. These mosaics are then transmitted to Dubai for display in the local TITAN installation. These mosaics are also ingested and processed by the AWDSS.

3. AWDSS HARDWARE

The hardware for the AWDSS is composed of several Linux computing clusters, each designed and implemented to accomplish a certain task (Figure 4). There are nodes for data ingest and algorithm control, numerical weather prediction, radiometer and profiler control, data storage, user interaction and display of meteorological data and products, and networking.

Figure 4 AWDSS Hardware Rack

4. THE SUITE OF AWDSS ALGORITHMS

The AWDSS contains of a collection of algorithms either licensed from leading research organizations and subsequently enhanced and tuned by WDT, or proprietary technologies developed by WDT and then deployed as part of the AWDSS.

At the heart of the AWDSS is the Nowcast Product Generator (NPG). The NPG is a WDT proprietary system comprised of commercial-off-the-shelf hardware and custom software that facilitates the data ingest, data decoding and storage, and proper execution of the algorithms.

4.1. *Microburst Detection Algorithm*

A version of the ASR-9 Microburst Detection Algorithm (AMDA; Cullen et al. 1999) which is similar to the MDA implemented as part of the Integrated Terminal Weather System (ITWS, Evans and Ducot 1994) was licensed by WDT from the Massachusetts Institute of Technology /Lincoln Laboratory (MIT/LL). AMDA provides the detection of divergent wind shear phenomena and estimates wind shear loss through those wind shear phenomena along the runway and along the arriving and departing flight corridors. The main input for the algorithm is the radar data from the EEC radar at the Dubai International Airport. The data interface to the algorithms and the adaptation to the EEC C-Band data were developed by WDT.

The runway alerting component of the software analyzes each microburst detection in relation to the runways and flight paths. Techniques to determine the flight path expected air speed loss are utilized to provide this information for alerting and display. Runway alerts are only generated if a microburst is overlapping the runway or if any part of it is within 500 meters of the runway (this buffer is variable).

4.2. *The Machine Intelligent Gust Front Algorithm (MIGFA)*

MIGFA was developed by MIT/Lincoln Laboratory (Delanoy and Troxel, 1993). Slightly different versions have been fielded as part of the TDWR system, the ASR-9 Wind Shear Processor (WSP), and the Integrated Terminal Weather System (ITWS). WDT has licensed this software, along with the runway alerting component, and made them part of the AWDSS. The main input for the algorithm is the radar data from the EEC radar at the Dubai International Airport. The data interface to the algorithms was developed by WDT.

MIGFA detects and predicts the movement of gust fronts and other synoptic and mesoscale fronts, sometimes only seen as "fine lines" of reflectivity on radar. Gust front detections (Figure 5) are executed utilizing an artificial intelligence technique called "functional template correlation"; this technique was adapted from a technique to automatically identify military vehicles utilizing satellite data.

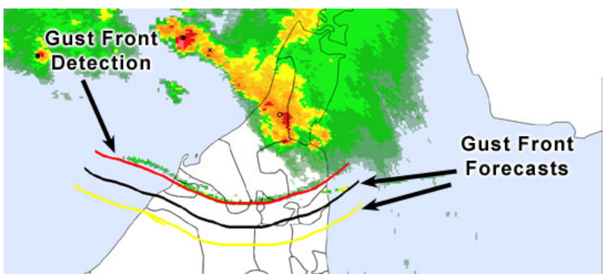

Figure 5 Gust Front Detection and Forecasts (10 and 20 minutes)

The runway alerting portion of MIGFA compares gust front detections and predictions and determines when the gust front is projected to impact the runways and/or flight paths. The algorithm also determines the strength of wind shear along the runway and along the arriving and departing flight paths for alerting and display.

4.3. *Radar-Based Storm Detection and Nowcasting Algorithms*

The radar-based storm detection and nowcasting algorithms are designed to operate on the radar data from the EEC radar located at the airport. Several of these algorithms have been licensed from the National Severe Storms Laboratory (NSSL), the University of Oklahoma (OU), and McGill University. They have been adapted by WDT to work with the EEC radar data and are also coupled with algorithms developed by WDT.

4.3.1. *Radar Artifact Removal and Gridding Algorithm*

This algorithm was licensed and adapted as part of the NSSL Warning Decision Support Integrated Information (WDSS-II Lakshmanan et al. 2007) software suite. It ingests radar data in real-time and provides a "clean" high-resolution 3-D grid of radar reflectivity by utilizing several sub-algorithms to ingest the data, perform quality control, and convert the data into a Cartesian dataset. Radar artifacts such as Anomalous Propagation (AP) and ground clutter are removed. This algorithm is an important quality control pre-processor applied to the EEC radar data before they are assimilated into any of the AWDSS algorithms.

4.3.2. *Storm Cell Identification and Tracking Algorithm*

The SCIT algorithm (Johnson et al., 1998) was also licensed from NSSL. It automatically identifies individual storm cells and diagnoses parameters associated with them, such as height, depth, echo top, echo base, Vertically Integrated Liquid (VIL), movement speed and direction, etc. In addition, the SCIT algorithm forecasts the movement of the identified storms.

4.3.3. *Storm Nowcasting*

WDT has licensed from McGill University a software system called MAPLE (Germann and Zawadzki, 2002) that predicts the evolution and movement of storms with great accuracy out to two hours in advance. The MAPLE system is a sophisticated expert system/artificial intelligence algorithm that was designed, developed, and thoroughly tuned and tested by a group of scientists over a 10 year period at McGill University in Montreal Canada. MAPLE examines a time sequence of up to six hours of radar data utilizing highly-tuned filtering, expert system, and artificial intelligence techniques to determine the movement and evolution of storms and their radar echoes. An important component of MAPLE is the capability to determine the different scales of storms and predict the lifetime of those scales based upon recent past history and the stability of the present environment. In this way, the motion and evolution of small scale storms are predicted out to 30-60 minutes while the motion and evolution of larger scale events are predicted to sustain for the entire nowcast length.

The output of MAPLE consists of nowcasts of radar reflectivity out to 2 hours in advance in 5 minute increments. These nowcasts are then utilized by other algorithms within the AWDSS.

4.3.4. *GIS-Based Asset Monitoring System (GAMS)*

GAMS utilizes a GIS database of locations and the output from MAPLE and the other algorithms to provide alerts and Estimated Time of Arrival and Departure information for any number of locations in the database. These locations can either be point locations, line segments (runways), or polygons. GAMS compares predicted threat areas with the location of each of the assets. If there is overlap between the predicted threat areas and an asset, an alarm is provided by the AWDSS. The content of the alarm is generated automatically by GAMS. This content includes which "asset" is threatened and the Estimated Time of Arrival and Departure of the threat (ETA/ETD).

4.4. *Fog Detection, Nowcasting, and Forecasting Toolkit*

WDT has developed a proprietary fog detection, nowcasting, and forecasting package. The Fog Detection and Nowcasting Toolkit (hereafter, "Fog Toolkit") alerts for the presence of fog and makes short term forecasts of fog formation and fog burn-off. The primary instrumentation used by the system is the Radiometer, which provides vertical profiles of temperature, relative humidity, and liquid water content that update every 2 minutes.

One primary sub-algorithm utilizes MSG satellite data to detect the presence of fog using the IR temperature difference between the 3.9 μm and 10.7 μm channels. The IR temperature data are utilized by the toolkit directly. Additionally, the IR temperature difference data are advected forward in time using the K-Means method (Lakshmanan et al. 2001) developed by NSSL as part of the WDSS-II. This output is also provided to the Fog Toolkit.

Inputs to the Fog Toolkit include trends of surface temperature, relative humidity, and cloud base height, along with the depth of the liquid water content, satellite-based fog detection and diagnosis, local surface observations, and the WRF forecast profiles from the AWDSS WRF system (Shaw et al. 2008). These data are then weighted using several fuzzy inference systems, which make decisions regarding the presence of fog, the short term threat of fog (1-3 hours), and the estimated burn-off time. If fog is present, the user will be alerted via a standard alert message which also includes the estimated burn-off time. If fog is not present, but expected to form within three hours, the user will be issued an alert which indicates the expected formation time.

4.5. *Detection and Forecasting of Wind Shear Experienced by Aircraft While Arriving*

The wind profiler produces automatic, near-continuous monitoring of the wind field throughout the bottom one-half of the troposphere and is therefore an excellent tool for estimating wind speed and the vertical shear of the horizontal wind. The issue for arriving aircraft is that while attempting to land they can descend into differing wind regimes. For example, a low level jet may form at the top of a night time inversion causing an acceleration of the winds just above the inversion. As aircraft approach the field, they can descend through the accelerating winds and into the inversion where there are very light winds. The aircraft can quickly lose airspeed thus causing the pilots to execute a missed approach. It is this type of wind shear that this particular algorithm detects. The vertical wind shear vector is calculated as the difference in horizontal winds between two successive heights normalized by the altitude difference of the measurements.

The effect of wind shear to a given aircraft is dependent on the shear along the glide slope. The Degreane wind profiler provides a wind shear calculation that was developed by Meteo-France (http://www.meteo.fr). This algorithm is utilized to calculate wind shear along the direction of the flight paths at each airport using the wind profiler data. From these wind speed and wind shear calculations, software developed by WDT calculates the estimated loss expected by an aircraft over a distance of a few hundred meters along the glide slope. The algorithm then provides estimates of the height the wind shear will be first experienced the location on the glide slope (e.g., 2 Mile Final) and the magnitude of the expected loss. If these calculations indicate a loss expected that is more than 20 kts (user threshold) then an alert is generated. Additionally, the WRF modeling system also provides forecasts of low-level wind shear, as well as types of weather phenomena that lead to vertical wind shear.

4.6. *Turbulence Forecasting System*

Unpredictable and rapid aircraft movements during flight that pose a safety risk to the crew and passengers are caused by atmospheric turbulence. WDT's Turbulence Detection and Forecasting Toolkit ("Turbulence Toolkit") consists of a suite of applications that use data from the wind profiler, radiometer, and WRF model output to detect, diagnose and predict the occurrence of atmospheric turbulence. The Turbulence Toolkit provides a suite of intermediate products to be used by meteorologists to assist them in diagnosing and forecasting the occurrence of turbulence, and provides automated detections (Figure 6) and forecasts of turbulence for non-meteorological users for alerting and support purposes.

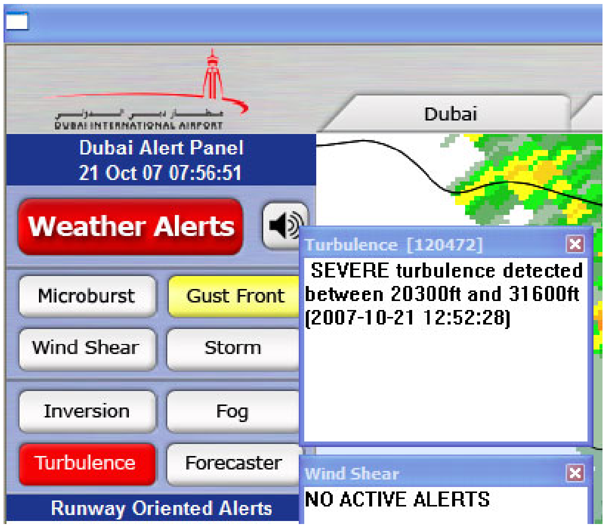

Figure 6 Turbulence Alert in the AWDSS Display

4.6.1. *Turbulence Diagnosis from Wind Profiler Data*

A primary culprit for dangerous turbulence is strong vertical wind shear, defined as a rapid change with height of the horizontal wind vector. The wind profiler produces automatic, near-continuous estimates of the wind field throughout the bottom one-half of the troposphere. From these data, rapidly-updating vertical wind shear estimates are available at numerous heights simply by computing the magnitude of the wind shear for each vertically adjacent set of wind observations within a profile. When the magnitude of the vertical wind shear exceeds a user-defined and adjustable threshold alerts of hazardous wind shear are generated.

4.6.2. *Turbulence Nowcasting from Wind Profiler Data*

Useful short-term forecasts (up to about 2 hours) of turbulence are made possible by performing a linear extrapolation of the wind field at all levels provided by the wind profiler. By extrapolating the most recent wind profiler data forward in time and computing the vertical wind shear from these extrapolated winds, short-term forecasts of increasingly dangerous—or increasingly benign—turbulence may be obtained. Beyond the time frame of about 2 hours, such extrapolated values are likely to deviate beyond acceptable error limits, especially during important, rapidly evolving situations such as the passage of troughs and frontal systems. For this reason, WRF model data must be employed to produce useful forecasts of turbulence beyond this time frame.

4.6.3. *Turbulence Forecasting from WRF Model Output*

The WRF modeling system (within the AWDSS) produces forecasts of turbulence for each grid point within the model three-dimensional domain. The turbulence index is computed using the algorithm of (Ellrod and Knapp, 1992). This index, which is the product of the vertical wind shear and horizontal deformation, has proven itself useful in identifying regions of hazardous turbulence.

4.7. *Flight Level Wind Diagnosis and Nowcasting System*

The Flight Level Wind Diagnosis and Nowcasting System predicts wind speed and direction changes based on a linear trend of wind profiler data. This combination of past and present wind data provides useful short-term nowcasts (up to about 3 hours) of the wind field at user-selected flight levels interrogated by the wind profiler. Beyond this time frame, however, such predicted values are likely to deviate beyond acceptable error limits, especially during important, rapidly evolving situations such as the passage of troughs and frontal systems. For this reason, the WRF numerical model forecasts are utilized for any forecasts beyond 3 hours.

4.8. *Inversion Detection and Nowcasting*

The radiometer provides continuous vertical profiles of temperature, humidity, and liquid water. Diagnosing the temperature sounding directly from the radiometer is an elementary process. This algorithm utilizes the radiometer temperature profiles and the trend of those profiles to detect and alert for inversions. The alerts generated by the Inversion Detection and Nowcasting Algorithm include the temperature at the surface, the temperature at the height of the inversion (highest temperature in the sounding), and the height of the inversion. In addition, trend information is provided including the direction of the trend (e.g., is the inversion strengthening or decaying?) and a short-term nowcast (up to 3 hours) of expected inversion strength (difference between the temperature at the bottom and top of the inversion layer).

4.9. *Low Altitude Wind Shear Detection*

WDT's Low Altitude Wind Shear Detection Algorithm (LAWSDA) is designed to alert users to low altitude wind shear based on two sub-algorithms. The first uses multiple wind observations from spatially adjacent observing stations and identifies sharp spatial gradients in wind vectors. The vector gradients are then projected on the different runway orientations and compared to user adaptable warning thresholds. The second sub-algorithm identifies rapid temporal shifts in wind vectors being observed at any given observing station, and compares them to user adaptable thresholds. Identifications of either wind shear type exceeding the corresponding LAWSDA thresholds are then issued to the NPG database for distribution to forecasters and air traffic controllers.

The motivation behind such an algorithm for the Dubai International system was to facilitate detection of shallow sea breezes that often move inland from the Persian Gulf and adversely affect arriving and departing air traffic. The same system will also aid in diagnosis of the strength of low altitude shear resulting from a convectively forced density current (i.e. gust front). The LLWSDA was tested using a sea breeze model, as well as by ingesting Oklahoma Mesonet observations during active cases of scattered convective storms.

5. WRF MESOSCALE MODELING SYSTEM

A version of the Weather Research and Forecast (WRF, Skamarock, et al. 2005) modeling system has been implemented as part of the AWDSS. It provides customized numerical weather prediction guidance with high spatial and temporal resolution in support of terminal and flight operations. Further information is provided in the companion paper by Shaw et al. (2008).

6. THE AWDSS DISPLAY SYSTEM

Two different display configurations are utilized in this implementation of the AWDSS, one for the meteorologists, and the other for use by the air traffic controllers.

6.1. *The AWDSS Air Traffic Control Display*

The AWDSS Air Traffic Control Display (ATC AWSD) has similar functionality to the Terminal Doppler Weather Radar (TWDR) and Integrated Terminal Weather System (ITWS) displays fielded by the United States Federal Aviation Administration. However, the AWDSS includes many more weather phenomena that need to be alerted for. As a result, managing these alerts in an innovative manner was critical. Importantly, the ATC AWSD is laid out in a simple, highly functional fashion with limited buttons and maximum visual cues when any weather phenomenon impacts or is expected (via the automated algorithms described above) to impact any flight or ground operations (Figure 7). The ATC AWSD is not a "sit-down" tool, but is instead an advisory tool for strategic as well as tactical planning of the terminal airspace. The ATC AWSD was developed to alert Air Traffic Control personnel to changing and hazardous weather conditions in the terminal area. The upper left portion of the display is an “Alert Panel”. In the case of potentially hazardous weather being detected or nowcasted in the terminal area, the large button on the top of the Alert Panel and one or more of the eight different boxes will turn a specific color to alert the user to specific conditions and an audible alert will be sounded. By changing the color of these boxes and providing an audible alert, the ATC AWSD draws the attention of the supervisor/manager to a situation that may be potentially dangerous or may require a change in the runway configuration or airspace.

Along the top of the display are 5 tabs, the first 4 allow the user to choose which airport in that region (Dubai, Jebel Ali, Sharjah, Ras Al Khaimah) they are viewing in a “local view”. The fifth tab (Regional) shows a regional view.

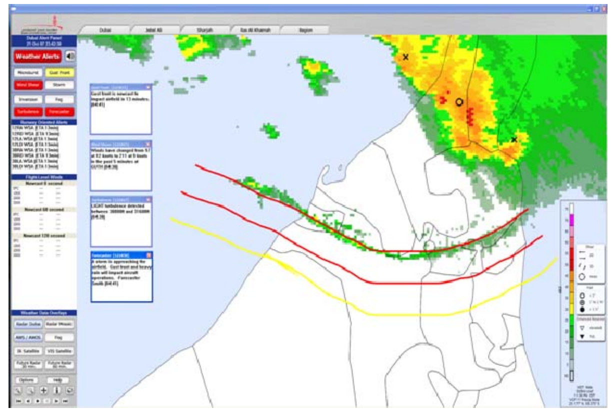

Figure 7 The ATC AWSD

On the upper part of the left column is a label that clearly defines which airport the alerts are issued. Below the label, the date and time are clearly displayed and are updated continuously. Under the date and time is a large button that is grey when there are no active weather alerts but changes to red and stays red for the duration of any weather phenomena impacting the area shown in the display. Otherwise, it will turn yellow if weather is nowcasted to impact the local area in the next 60 minutes (user selectable threshold). Any “red alert” will override a “yellow alert” causing the Weather Alert bar to stay red as long as any weather alert is active for the local area. To the right of the Weather Alert bar is a toggle for turning on and off audible alerts. Under the Weather Alert and Audible buttons are a series of “Individual Weather Phenomena Alert” buttons identifying what weather alert is occurring at that time. Buttons turn red when a weather alert is detected or yellow when a weather phenomenon is nowcasted to occur within 60 minutes. If there are no detections or nowcasts for that phenomenon, the button remains grey. Clicking on any of these buttons brings up a small window that provides information about the alert that was generated as well as Estimated Time of Arrival and Departure information about the weather phenomena if it is available. These button labels indicate the type of alert being generated, the “forecaster” button is an alert sent manually by a forecaster at the Dubai Met office.

6.1.1. *Runway Oriented Alerts*

Below the center field wind line is a series of lines of text. These lines of text are simple coded messages that are specific to each possible flight path for arriving and departing aircraft. For example, “12RA” is decoded as the flight path for arriving aircraft on the 12 Right runway. If a weather alert of any kind is generated on this runway or along the expected flight path out to 3 nautical miles from the runway a coded message will be placed to the right of the moniker. For example:

12RA MBA 30K- 1MF

This message is decoded as: “on 12 right approach there is a Microburst Alert, expect 30 knot loss beginning at 1 Mile Final." If the alert is for the actual runway then the letters "RWY" will be used instead. These designations are set to indicate the location where the aircraft will first experience the hazard.

6.1.2. *Weather Data Overlay*

In the column under the Runway Oriented Alerts is a section labeled "Weather Data Overlays" consisting of a series of buttons which allow the user to toggle on or off the overlay of various weather data including radar reflectivity data, surface observations, radar mosaics, fog identified from Satellite, MSG IR Satellite data, MSG Visible Satellite imagery, 30 minute nowcasted reflectivity and 60 minute nowcasted reflectivity (from MAPLE forecasts). The forecasted reflectivity is displayed in a different color scale than the present reflectivity so that the user can easily distinguish between the two and avoid confusion.

6.1.3. *Main AWDSS Display*

The larger display is a version of the WeatherScope™ display capability developed by the Oklahoma Climatological Survey and licensed by WDT. WeatherScope integrates real-time weather and GIS data into a single display. WeatherScope is an interactive display capability that is delivered as a dynamically linked library (DLL) component of a stand-alone application. WeatherScope can inherently display many meteorological data streams in their standard format whether the data are point observations, gridded, or in azimuth/range format. The core functionality of WeatherScope is that it allows a user to interact with the weather data by zooming, panning, etc. even while images are animating. Also, any GIS map layer can be displayed within WeatherScope allowing the user to toggle on and off those layers as they choose.

Within WeatherScope, the runways are color coded to indicate weather alerts on the runway or along the flight path. When no weather alerts are present, the runways and flight paths are black (user adaptable). When alerts occur, the runway and the flight path are changed to red. Only detections of hazardous weather phenomena will cause the runway colors to change, and nowcasts of those phenomena will only change the color of buttons on the left. This can be configured differently depending on the preferences of the meteorologists or air traffic control personnel.

6.2. *The Met Aviation Weather Situation Display*

The Meteorologist AWDSS Display (hereafter "Met AWSD") has three core functions. These core functions include 1) providing the same display and functionality as is used in ATC operations, 2) providing capabilities to analyze and interrogate meteorological data and algorithm products in detail, and 3) providing a method whereby meteorologists can have the option of verifying alerts before they are sent to the ATC Display as well as allowing them to send their own alerts to the ATC display.

6.2.1. *Overview*

The Met AWSD is optimized for a display on dual widescreen monitors. Figure 8 is a sample of the Met AWSD Launch Pad that first appears when you start the display. From the Launch Pad, the user can select any one of the 16 buttons. On the left of the AWSD Launch Pad is a Weather Alert button, that turns Red (weather hazard detected at any airport) or Yellow (weather hazard nowcasted at one of the airports) depending upon weather conditions at any of the airports. Clicking on the Weather Alert Button opens up a small window with information about the alert or alerts. The Audible Alarm Function operates the same as the ATC AWSD version, with alerting for one airport or for multiple airports (user adaptable option). The application buttons launch software to control the radiometer and profiler, display a system status page, view model output, launch the sounding analysis program, and launch the radar analysis program. The system status button is color-coded to indicate the overall health of the system.

Figure 8 Launch Pad

6.2.2. *Sounding Analysis Software*

A custom version of the RAOB software, developed by Environmental Research Services, has been implemented as part of the Met AWSD. RAOB is a multi-functional sounding analysis program. Data from the radiometer and wind profiler are displayed in RAOB and color-coded time-height diagrams are available. In addition, the user can create a variety of sounding diagrams, 3-D hodographs, time & distance based vertical cross-sections, mountain wave turbulence diagrams, and view forecast soundings from WRF output (Figure 9).

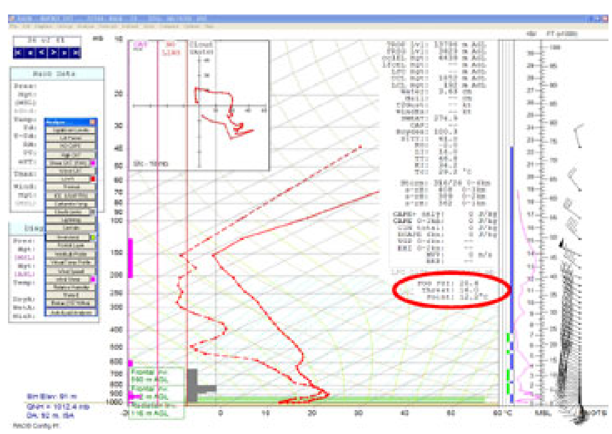

Figure 9 RAOB Display

6.2.3. *Radar Analysis Toolkit*

The Radar Data Analysis Toolkit (hereafter “Radar Toolkit”) is built upon the WeatherScope plug-in capability that was described earlier. The Radar Toolkit has a robust capability to examine and analyze every elevation angle of reflectivity and velocity data from the EEC radar as well as the radar-based algorithm output (Storm Tracking, MAPLE nowcasts, gust front detections, etc.). The EEC radar data can be displayed overlain upon high resolution terrain and any GIS layers (roads, streams, runways, flight paths, power utility lines, etc.). WDT has delivered this capability as part of our Weather Decision Support Systems to many clients including the Italy ARPAV Centro Meteorologico di Teolo, the Lower Colorado River Authority, over 100 electric utilities in the United States and many other organizations.

6.2.4. *Nowcast Product Generator Browser*

WDT has developed a custom web-based system status monitor. This monitor allows the user to monitor the overall health of the servers, Met displays, ATC displays, and algorithm performance (Figure 10). Additionally, the user is able to view some of the raw data and algorithm output.

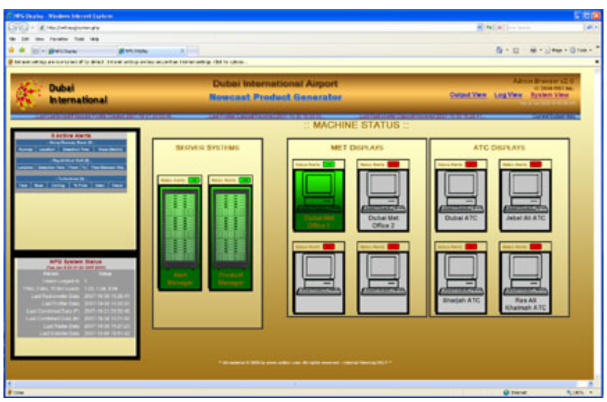

Figure 10 System Status Monitor Web Site

7. SUMMARY

The AWDSS is designed to support airport operations at the Dubai International Airport as well as the Dubai World Central International Airport at Jebel Ali in the United Arab Emirates. However, the system can be customized and deployed at any other airport in the world. The primary purpose is to provide timely guidance to the forecasters and ATC personnel concerning meteorological hazards and a common situational awareness between them. The system combines the latest meteorological hazard prediction technology with state-of-the-art remote sensing hardware and a user-friendly interface.

References

Cullen, J., W. Pughe, S. Troxel, and O. Newell, 1999: “ASR-9 Microburst Detection Algorithm (AMDA) for WSP,” Lincoln Laboratory Project Report ATC-273.

Delanoy, R.L., and S.W. Troxel, 1993: “The Machine Intelligent Gust Front Algorithm”, MIT Lincoln Laboratory, Project Report ATC-196.

Dixon, M., and G. Wiener, 1993: TITAN Thunderstorm Identification, Tracking, and Nowcasting – a radar-based methodology. *J. Atmos. Oceanic Tech.,* **10,** 785-797.

Ellrod, G.P., and D. I. Knapp, 1992: An objective clear-air turbulence forecasting technique: Verification and operational use. *Wea. Forecasting,* **7,** 150-165.

Evans, J.E., and Ducot, E.R., 1994: The Integrated Terminal Weather System (ITWS), *The Lincoln Laboratory Journal,* **7(2),** 449-474, MIT/LL

Germann, U. and I. Zawadzki, 2002: Scale-dependence of the predictability of precipitation from continental radar images. I: Description of the methodology. *Mon. Wea. Rev.*, **130,** 2859-2873.

Johnson, J. T., P. L. MacKeen, A. Witt, E. D. Mitchell, G. J. Stumpf, M. D. Eilts, and K. W. Thomas, 1998: The Storm Cell Identification and Tracking (SCIT) algorithm: An enhanced WSR-88D algorithm. *Wea. Forecasting,* **13,** 263-276.

Lakshmanan, V., R. Rabin, and V. DeBrunner 2001: Segmenting radar reflectivity data using texture. *30th International Conference on Radar Meteorology*, American Meteorological Society, Munich, 50-52.

__________, V., T. Smith, G. Stumpf, and K. Hondl 2007: The Warning Decision Support System–Integrated Information, *Wea. Forecasting,* **22,** 592–608.

Shaw, B.L., P.L. Spencer, R.L. Carpenter, Jr., and C.A. Barrere, Jr., 2008: Implementation of the WRF model for the Dubai International Airport Aviation Weather Decision Support System. Extended Abstracts, *13th Conf. on Aviation, Range, and Aerospace Met.,* New Orleans, LA, Amer. Met. Soc. [this volume].

Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, W. Wang and J. G. Powers, 2005: “A description of the Advanced Research WRF Version 2.” NCAR Technical Note, NCAR/TN-468+(STR), National Center for Atmospheric Research, Boulder, CO, 88 pp.