6.9 **LOW ALTITUDE WIND SHEAR HAZARDS: GROUND BASED DETECTION AND COMMERCIAL AVIATION USER NEEDS**

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1. INTRODUCTION*

The aviation community has made great strides over the last 30 years in understanding and avoiding the low altitude wind shear hazard. This success has been, in part, due to the aviation weather community's progress in detecting and distributing real time information regarding these hazards. Both ground and aircraft-based wind shear alerting systems have been introduced over the last 25 years to support aviation safety. This article focuses on the ground-based wind shear hazard measurements and the associated alert accuracy as well as the information needs of commercial aviation.

The intended audiences are commercial airline pilots operating internationally, Aviation meteorologists and representatives of states developing and/or reevaluating wind shear detection systems.

A review of the current wind shear detection systems deployed at airports in Canada; Japan; The Netherlands; Hong Kong, China; and the United States (US) will provide the international perspective.

A comparison of features common to all countries will be based on ICAO standards. Identification of the differences in wind shear systems will be based on three categories:

1. Detection System(s) in Use and Airports at which systems are deployed.
2. Distribution Method(s) & Distribution System(s) employed for Alerts and Advisories.
3. Terminology Used to describe the hazard.

Accuracy and detection capability of existing systems in the US will be examined in detail. In the U.S., alerts are disseminated to pilots via either air traffic controllers or the Terminal Weather Information for Pilots (TWIP) system. Two previous analyses of the TWIP system alert reliability were conducted and reported at 9th and at 10th Conferences on Aviation, Range, and Aerospace Meteorology [Fahey et al, 2000 and Fahey et al, 2002]. An updated report providing estimated detection accuracy using the last six years of continuous records will be provided. Focus is on wind shear events with either weak convection or no convection present.

2. HISTORICAL PERSPECTIVE – WIND SHEAR CAUSES & DETECTION SYSTEMS

The development of systems to detect and alert regarding low altitude wind shear hazards have been driven by meteorological understanding, capability of technology, aircraft accidents and the fact that the most significant type of wind shear hazard is not the same through out the world. For example, in the central and eastern U.S. wind shear associated with convection is usually the most common and significant. In Hong Kong, the most common cause for wind shear is the disruption of the flow of air by the hills surrounding the airport.

2.1 Frontal Shear

Northwest Airlines (NWA) was reporting and forecasting wind shear as early as 1962. At that time the focus was on wind shear produced by synoptic scale frontal systems, specifically low altitude warm and cold front shears [Sowa, 1974]. The wind velocity reported at the airport was used as an estimate of the wind direction and magnitude below the warm frontal surface. A calculation of the gradient wind based on surface isobar spacing and curvature upwind from the airport in the warm sector was used as an estimate of the wind velocity above the frontal surface.

2.2 Convection Induced Shear

Gust fronts and microbursts are clearly identified today as two separate phenomena, all be it, both related to convection. In the early years of commercial aviation, 1960's and prior, a wind gust observed at an airport would simply be characterized by a meteorologist as either

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synoptic scale, terrain or thunderstorm induced. Maintaining a Flight Operations policy to avoid all thunderstorms during landing and takeoff was relatively painless, in theory and usually in practice, in the early years of aviation. On time performance, high air traffic volume, all-weather landings and optimization of aircraft utilization were not emphasized at the level they are today.

In the mid to late 1970's, as a result of three separate aircraft accidents, the aviation industry began to recognize the risks posed by low altitude wind shear associated with relatively small cells of convection, previously considered benign. The existence of strong downdrafts in small cells were inferred in all three accident investigations and were coined "downbursts" [Fujita and Byers, 1977]. It was theorized that all three accidents occurred as aircraft, either descending or climbing, lost altitude while experiencing strong wind shear inside a "downburst" cell. [Fujita and Caracena, 1977]. The introduction of the Low Level Windshear Alert System (LLWAS), a network of ground based anemometers, was the first observational network and alerting system in the U.S. designed to address this hazard [Goff and Gramzow, 1989]. It was the JAWS (Joint Airport Weather Studies) effort [McCarthy et al, 1982] that helped set the stage for the introduction of the next generation of wind shear alerting systems in the U.S., the Terminal Doppler Weather Radar (TDWR) for convection related wind shear.

2.3 Terrain Induced Shear

A system to detect low-level wind shear hazards, including terrain induced wind shear was introduced in September 1979 at the old Hong Kong International Airport at Kai Tak when an anemometer based experimental system, comprising five ground based anemometers, was introduced. Then in January 1984 an early generation Doppler Acoustic Radar (DAR) system was also introduced and used on an experimental basis [Royal Observatory, 1985]. But due to design limitation, the update frequency of the DAR system was restricted to every 10 minutes, while in contrast the anemometer based system was updated every 30 seconds. [Royal Observatory, 1985]

The anemometer based system was subsequently expanded to comprise nine anemometers to detect and warn of low-level wind shear and crosswind at the aerodrome. The DAR was also replaced by a boundary-layer Doppler wind profiler. This system, known as the Strengthened Windshear and Crosswind Warning System (SWCWS) was declared operational in the 1990s.

Aircraft landing at the new Hong Kong International Airport at Chek Lap Kok must, at times, deal with wind shear and/or turbulence hazards. These events are usually the result of air flowing across hilly terrain [notably Lantau Island south of the airport], with sea breeze, thunderstorm and low-level jet also contributing. The most frequent causes are due to strong winds crossing Lantau Island in spring and during the passage of tropical cyclones. As a result, significant investment was made in a TDWR, LLWAS and wind profiler based wind shear detection system when the new airport was built and opened in July 1998. While the TDWR has proved to be effective in rainy weather, reports received from aircraft pilots landing at or taking off from the airport indicated that low-level wind shear was also occurring under clear-air conditions [Choy et al, 2004]. Additional instrumentation and wind shear detection algorithms have been added to address these previously undetected wind shear events (see section 3.5).

2.4 Other Causes of Shear

Temperature inversions and sea breeze induced low level convergence lines are two other causes of wind shear. Detection systems, currently operational, are designed to detect sea breeze induced shears. Reliability in detection of temperature inversion as well as warm front induced shears is questionable due to the fact that the location of the hazards is not reflected at the surface at the airport and the hazard occurs entirely at an elevated level above the surface.

3. WIND SHEAR ALERTING: AN INTERNATIONAL PERSPECTIVE

Expansion of international aircraft operations and deployments of new or upgraded wind shear detection systems are occurring. As a result there is a need for pilots to understand the similarities and differences between wind shear alerting systems around the world. There is also a need for representatives from governments around the world responsible for procurement of new and continuation of existing systems to have a similar appreciation. A brief summary of detection systems in use; distribution methods employed for alerting; and terminology used to describe the hazard will be provided. The airports selected are of operational interest to Northwest Airlines (NWA).

3.1 Similarities Worldwide

The current international standards and recommended practices on wind shear warning are stipulated in Chapter 7 and Appendix 6 of Annex 3 to the Convention of International Civil Aviation [ICAO, 2004]. In particular, Appendix 6 para. 6.1 of Annex 3 recommends that "Evidence of the existence of wind shear should be derived from:

a) ground-based wind shear remote-sensing equipment, for example, Doppler radar;

b) ground-based wind shear detection equipment, for example, a system of surface wind and/or pressure sensors located in an array monitoring a specific runway or runways and associated approach and departure paths;

c) aircraft observations during the climb-out or approach phases of flight to be made in accordance with Chapter 5; or

d) other meteorological information, for example, from appropriate sensors located on existing masts or towers in the vicinity of the aerodrome or nearby areas of high ground."

To the best of our knowledge, while a number of airports in North America and Asia have installed automated ground-based wind shear detection systems which provide wind shear alerts to aircraft in real time via ATC or air-ground datalink, wind shear warnings based on pilot reports and forecaster's assessment of available weather data are provided at the other airports, e.g. via the automatic terminal information service (ATIS). A proposal to distinguish the wind shear alerts (based on automated systems) from the wind shear warnings (based on pilot reports and forecast) is being considered by ICAO.

Some concern has been expressed regarding the continued use of the term "warning" to describe both an observed hazard (pilots reports) and a potential but not necessarily current observed hazard (forecast).

3.2 Canada Implementation

Air traffic controllers in Canada relay PIREPs of wind shear to departing and arriving pilots. Currently, as of October 2005, there are no automated wind shear detection systems installed at any Canadian airports [Chretian, 2005].

3.3 Japan Implementation

In Japan, wind shear information is delivered verbally to pilots of departing and landing aircraft by the ATC controller. The wind shear information source can either be from actual pilot reports or mechanically detected data by Terminal Doppler Radar (TDR) (if installed). Six international airports in Japan have TDR: Sapporo (RJCC), Narita (RJAA), Haneda (RJTT), Chubu (RJGG), Kansai (RJBB) and Naha (ROAH).

In Japan an alert message is generated by the Civil Aviation Bureau's system called DRAW, which includes other observational data also. The alert message is made available to the ATC controller for relay to arriving and departing aircraft. It is also delivered to the airport meteorology office at the same time. Currently, automated uplink of wind shear information to the flight deck has not been implemented. During preparation for DRAW implementation, representatives for pilots from Japanese airlines, Japan Meteorological Agency and Civil Aviation Bureau met. A preference for verbal relay of wind shear alerts by controller was indicated vs. automated uplinking. Also the group requested that the source of wind shear alert information be clearly identified, specifically whether the source is from a PIREP or from the automated detection system [Todo, 2005].

3.4 The Netherlands Implementation

No documentation has been identified regarding implementation of automated wind shear detection in The Netherlands.

3.5 Hong Kong, China Implementation

Since 2000 the Hong Kong Observatory (HKO) implemented several new facilities to enhance the original TDWR based wind shear detection system. These include five strategically located weather buoys to the east and west of the airport, several anemometers on hilltops and valleys over Lantau Island, and a pulsed Doppler LIght Detection And Ranging (LIDAR) system which was installed at the airport in mid 2002 [Shun 2004].

Based on the wind measurements of the five weather buoys and seven anemometers at the airport and a nearby island, HKO developed an Anemometer-based Windshear Alerting Rules – Enhanced (AWARE). AWARE was found to be very effective in extending the coverage of the surface anemometer network in detecting wind shear caused by sea breezes, gust fronts and low-level shear lines induced by terrain. The LIDAR has demonstrated its capability in detecting wind shear in clear air when the laser beam is not attenuated or blocked by precipitation and water droplets. The LIDAR has proved useful in supplementing the TDWR in wind shear detection for a much wider range of weather conditions [Shun 2004].

Alerts for possible wind shear within 3 nm of the runway thresholds are automatically generated by computation algorithms using data from the suite of weather sensors. The automated alerts for wind shear are classified into two levels: "Microburst Alert" (MBA) for wind shear with headwind loss of 30 knots or greater and accompanied by precipitation and "Wind Shear Alert" (WSA) for wind shear with headwind loss or gain of 15 knots or greater (except MBA). A consolidated alert is given for each approach/departure corridor based on a priority system which takes into consideration the severity of the alerts and the confidence level of the different data sources which generate the alerts [HKO/ IFALPA, 2002]. The automated alerts are updated at a frequency of at least once per minute for relay to aircraft via ATC.

Following the "First Encounter – Maximum Intensity" principle adopted by TDWR, the automated wind shear alerts used to be provided in the form, for each runway corridor, "WSA +20KT 2MF" ("+" verbalized as "PLUS" and "2MF" verbalized as "two mile final"). Recognizing the transient and sporadic nature of terrain-induced wind shear [HKO/IFALPA, 2002] and that not all pilots are familiar with the "First Encounter – Maximum Intensity" principle, in consultation with pilots, the format of the alert relayed to the aircraft by ATC was changed w.e.f. February 2003 to the form "WSA +20KT APP" ("APP" verbalized as "approach") without reference to the specific location (i.e. runway, 1 NM, 2 NM or 3 NM) along the runway corridor concerned.

The wind shear alerts, supplemented by forecaster's assessment and actual pilot reports, are also broadcast as warnings on the automatic terminal information service (ATIS) [on both the conventional voice-ATIS and the D-ATIS via air-ground datalink] to facilitate pilots to prepare for their take-off or landing in advance. A warning will be given as "FCST", viz. "forecast", when the information is forecast by the forecaster, or "FCST AND REP", viz. "forecast and reported", when the information has been confirmed by pilot reports in the past 30 minutes [Hong Kong Civil Aviation Department, 2005]. Furthermore, the wind shear warning on ATIS also carries the specific runway corridor(s) over which the warning is effective, e.g. "SIG WS FCST AND REP 07L".

Work is underway to implement a LIDAR based wind shear detection algorithm developed by HKO to generate automated wind shear alerts, after integrating with the alerts from the other weather sensors (e.g. TDWR, AWARE), for relay to aircraft via ATC [Chan et al, 2006]. Arrangements are also being set up to relay the automated microburst alerts generated by the TDWR via the air-ground datalink Terminal Weather Information for Pilots (TWIP), on a trial basis (see section 3.7).

3.6 United States Implementation

The United States wind shear detection systems are the responsibility of the Federal Aviation Administration (FAA). As of October 2005 there were 117 airports in the contiguous US with FAA installed wind shear detection systems in operation. Three different basic systems have been deployed. The Low Level Wind Shear Alert System (LLWAS) uses anemometers. The Terminal Doppler Weather Radar System (TDWR) uses a separate stand alone radar installed in the vicinity of the airport. The Weather System Processor (WSP) uses air traffic's Aircraft Surveillance Radar (ASR) with added software.

Currently there are 40 airports with only LLWAS. They are identified as LLWAS-RS (Relocation and Sustainment). Currently there is no communication infrastructure in place for wind shear information at these 40 airports to be integrated into the TWIP wind shear information distribution system.

There are 47 locations equipped with TDWR. Two of the 47 sites are used exclusively for testing and training. These two sites are located at Program Support Facility (PSF) and the Oklahoma City Training Academy (OSF) but they are not located at airports used by commercial aircraft. In addition, one of the TDWR sites serves 2 airports, LGA and JFK, resulting in a total of 46 airports able to be served by TDWR. But 3 TDWRs at 3 airports have not been activated. They are Las Vegas, NV (LAS), Phoenix, AZ (PHX) and San Juan, Puerto Rico (SJU). The final result is 42 TDWRs generate wind shear information for 43 airports. The wind shear information at these 43 airports is distributed via the TWIP system.

Two additional implementation details regarding TDWR and TWIP implementation. At 9 airports (ATL, DEN, DFW, MCO, MSY, ORD, LGA, STL & TPA) of the 43 airports with TWIP capability an LLWAS-NE++ (NE=Network Expansion, ++ = software rehost) is operational in addition to the TDWR. Wind shear information can be generated by either the TDWR or the LLWAS-NE++ or both at these 9 airports. Fahey et al, 2000 provides a description of the integration/merging algorithm used at these 9 airports (Note: LGA received this capability in Nov 2001 and was the last to be implemented of the 9 airports).

The final implementation detail regarding TDWR and TWIP. Currently at 19 of the 43 airports with TWIP capability, information from the nearby National Weather Service WSR-88D radar as well as other sensors and data sources are included as part of the Integrated Terminal Weather System (ITWS). There are currently 11 ITWS operational and these 11 ITWS sites provide information including wind shear alerts for 19 of the 43 airports with TWIP capability.

Finally there are 34 airports with WSP capability. The WSP was originally designed with the capability to transmit wind shear information to the TWIP communications system for distribution to pilots, dispatchers and meteorologists. Currently, October 2005, this capability has not been activated.

Alerts at all 117 airports are relayed verbally by the Air Traffic tower controller to aircraft at the time that the landing or departure clearance is given. Delivery is only required if the intended runway or extended threshold is impacted by the wind shear hazard.

In 1993 testing of an additional distribution method, Terminal Weather Information for Pilots (TWIP) was begun by the FAA and participating airlines.

The goal of TWIP is to make available to pilots, flight dispatchers and airline meteorologists, wind shear alert information that was traditionally only available to Air Traffic Control. To accomplish this goal it was proposed that additional software be written and integrated with the existing TDWR control and display unit (CDU) located in every FAA tower and Approach Control facility served by a TDWR. See Fahey et al 2002 for details about TWIP implementation in the 1990's. Currently the TWIP communication system is integrated into all versions of TDWR implementation, including airports served by the ITWS and LLWAS-NE++ variations. TWIP messages are not available for the LLWAS-RS nor for the WSP equipped airports.

There are two methods for disseminating wind shear information via TWIP: Request/Reply and Send/Cancel. A description of both can be found in Fahey et al, 2000.

3.7 Northwest Airlines Implementation

NWA has been automatically data-linking TWIP alerts to company aircraft since the 1993 demonstration via the Send/Cancel method. The TWIP uplink capability used by NWA is an adapted version of the Turbulence Plot System (TPS) distribution software originally developed in the 1980's and part of NWA's FAA approved Enhanced Weather INformation System (EWINS). NWA Pilots, Dispatchers and Meteorologists all are provided unsolicited access to the TWIP wind shear messages via the Send/Cancel distribution method.

Although the TWIP messages are updated every one minute when there is a storm and/or wind shear present, the Send/Cancel distribution method identifies all "Send" messages as valid for 20 minutes. The message is then only updated with another "Send" message when the hazard has significantly diminished or increased. If the hazard has ended and no new hazard is detected for 5 consecutive minutes, a "Cancel" message is sent.

Up until February 2005 NWA was using the original convention, accepted in 1993, of labeling all TWIP messages as "Alerts". But due to the facts that, first, all TWIP messages do not specify the runway affected, and, second, Send/Cancel TWIP messages are not updated every minute when a hazard is present, NWA decided to use the NWA TP distribution software to label all TWIP "Advisory" rather than "Alert". In this way the TWIP Send/Cancel message is now consistent with the terminology used by the FAA. The FAA defines all wind shear hazard information generated by the automated systems, LLWAS-RS, TDWR, TDWR/LLWAS-NE++, TDWR/ITWS or WSP and relayed to pilots in the same minute it is generated by the tower controller as "Alert". But wind shear hazard information contained on ATIS are more general and are identified as "Advisory" by the FAA. ATIS does not include information about the runway affected, and they are valid for 20 minutes. Similarly, the TWIP Send/Cancel messages are valid for 20 minutes.

In February 2005 NWA instituted a Flight Operations policy that prohibited departure or arrival on a runway with a current wind shear "Alert" in effect, but allowed the option of continuing an approach or departure with caution when a wind shear "Advisory" was in effect. Based on the FAA definitions of "Alert" and "Advisory", and the reasoning listed above, NWA determined that it was best to identify TWIP Send/Cancel messages as "Advisory" rather than "Alert". As a result all reference to NWA TWIP Send/Cancel messages in this article will be referred to as "TWIP Advisories" rather than "TWIP Alerts".

In November 2005 the concept of an "Alert" as a currently occurring weather hazard and an "Advisory" as a potential but not necessarily current weather hazard for an aircraft's exact area of operation, was expanded to include all weather hazards covered by the NWA TPS [Fahey et al 2005].

HKO and NWA are currently, October 2005, testing the ability to deliver Send/Cancel type wind shear hazard messages to NWA aircraft arriving and departing Hong Kong International Airport at Chek Lap Kok (HKG/VHHH).

3.8 Other Implementations

In Taiwan, the Institute for Information Industry and the Civil Aeronautics Administration teamed with the National Center for Atmospheric Research, Research Applications Laboratory to develop the Taiwan Advanced Operational Aviation Weather System (AOAWS). The Terminal Aerodrome Windshear System was implemented in 2001 at three airports as part of the AOAWS. The two airports of interest to NWA, Sungshan, Taipei (TPE/RCTP) and Kaohsiung (KHH/RCKH) both have LLWAS and the originally planned ASR-9 Windshear Processor installation at RCKH has not been implemented.

The Japanese TDR is also installed at Incheon International Airport, Republic of Korea (ICN/RKSI); New Kuala Lumpur International Airport, Malaysia (KUL/WMKK); and Changi International Airport, Singapore (SIN/WSSS) [ICAO, 2005].

4. CURRENT WIND SHEAR SYSTEM ACCURACY & DETECTION CAPABILITY

Focus will be on the Hong Kong and U.S. systems.

4.1 Hong Kong System accuracy

In 2003, with the use of the additional data from the weather buoys and the LIDAR by the aviation forecasters, based on pilot wind shear reports, the probability of detection (POD) of HKO's wind shear alerts and warnings reached 95 per cent [see Figure 1], with the false alarm rate on a continual decreasing trend.

4.2 U.S. Systems Accuracy – FAA Stats

The FAA's Probability Of Detection (POD)/False Alarm Rate (FAR) for the TDWR meets the specification performance values of detecting at least 90% of the wind shear losses, while false alarming less than 10% in terms of wind shear losses. Losses meet specs in east and central states, but do not meet specs out west (SLC, LAS and PHX in particular) [Keohan, 2005]. WSP is now operating successfully at 34 airports across the USA. The FAA does not require sites to collect data routinely, therefore currently it is not possible to arrive at any objective measure regarding WSP performance. The FAA however provides support and data analysis for sites who request this assistance. For the most part, WSP performance seems to be satisfactory, where air traffic enjoys WSP capability to clearly display six level weather and its capability to provide wind shear alerts. In several sites seasonal false alerts are found during inversion conditions, in particular during sunrise and sometimes sunset. This is attributed to bird activity or pollution with typical bird signature often observed

The FAA has not collected any performance statistics for the LLWAS-RS. In addition, there have been no FAA studies to collect performance statistics on the LLWAS-NE since the major system modification (LLWAS-NE++) in 2001. All POD/FAR information for LLWAS-NE is for the old system, prior to the system upgrade that includes ultrasonic anemometers and state of the art remote station electronics.

4.3 TWIP Advisory Accuracy-NWA Estimate

Individuals at NWA have been documenting the accuracy of TWIP Advisories since the mid–1990's. Rigorous efforts were begun in 1998 when a 2 month study was conducted. Beginning in January 2000 continuous accuracy estimates have been maintained. Two previous studies have been completed. [Fahey et al, 2000] reported on accuracy estimates for the 1998 and January-May 2000 periods. [Fahey et al, 2002] reported on January 2000 through January 2002 accuracy estimates.

The studies in 2000 and 2002 as well as this study focused only on the "No Storms" advisories. The TWIP system labels all messages in which less than 30dBZ radar reflectivity is detected as "No Storms Within 15nm". This 30dBZ threshold is the same as the NWS scale of less than or equal to level 2 reflectivity.

For the 69 month period of this current study (January 2000 to September 2005) a total of 18,232 "No Storms" Advisories were generated. Figure 2 displays a monthly total of all TWIP advisories with "No Storms".

It is interesting to note that the three month period, March through May, is consistently a period of high volume of "No Storm" Advisories. The annual average number of alerts for the March-May 3 month period is 1088. This is almost double the annual average number of alerts for the October-December period (593). It is also approximately 200 more than the June-August 3 month period of 893.

Of the total, 16,233 were Advisories for less than 30kts. The remaining 1999 Advisories were for 30kts or greater. The three NWA studies also all focused on only those Advisories of 30kts or greater "Strong Advisories". In this current study, "No Storm" advisories, containing "Heavy Precip" were also categorized as "Strong Advisories"

The accuracy of the one thousand nine hundred and ninety nine NWA TWIP "No Storm", "Strong Advisories" were estimated in the following manner. The airport weather observations (METARs) were used to determine whether an event fit into one of three categories: "valid", "questionable"/overstated or "false". A 4th category was labeled "missing" when METAR data was not available.

Other wind shear alert system performance studies have used the TDWR radar data, LLWAS winds, or a combination of both via post-processing to estimate truth [Isaminger et al, 2000]. While this has been the preferred method of some researchers, the data was not available for this study. Until March 2004 most of the data from the systems was not routinely being archived.

4.4 Advisories (30Kts & Greater) Accuracy

Based on the METAR evaluation technique, it was estimated that 62% of Advisories containing "No Storms" and also "Strong" (containing either, shear values of greater than or equal to 30 knots, or the Heavy Precip comment) were erroneous. (see Figure 3.)

In January 2000 there were 32 airports with TWIP advisory capability. CLE was activated in February 2000. BNA, IND, and SDF were activated in September 2000. SLC was activated in March 2001. ADW was activated sometime between March 2001 & March 2002, but since NWA does not have scheduled operations to that military base, no ADW TWIP messages were archived. FLL was activated in January 2002. MDW was activated in April 2002. JFK and LGA were activated in May 2002. EWR was activated in May 2003. To determine if there has been an improvement in accuracy of "Strong" "No Storm" TWIP advisories between January 2000 and September 2005, the number of false advisories by month were examined. Figure 4 displays the ratio of false advisories generated in a month normalized to the number of airports with TWIP advisory capability. As a result a monthly value for all 69 months of the study is displayed in Figure 4 as a percentage of active TWIP stations.

Has there been an improvement in accuracy since the last study was completed in early 2002? The initial qualitative conclusion is no. November 2003 had the highest value of any month at 219%. Although the entire year of 2004 was relatively low, January and March 2005 had the 5th and 8th highest values of the 69 months at 121% and 90% respectively.

Quantitatively, the 2002 study showed that 62% of the "No Storms" advisories, those of 30kts or greater, were classified as false. As shown in Figure 3, the ratio is virtually unchanged, with 62% estimated as false for the total period Jan'00 – Sep'05.

4.5 Strong False Advisories

Strong False Advisories, were then divided into 6 subcategories: Technician Error, Faulty Sensor, Heavy Precip, Gust Front Algorithm issues, Gusty Winds, or Unknown (see Figure 5).

The Gust Front Algorithm subcategory will be examined further since it has the largest number of false alerts. Figure 6 shows the subdivision of possible causes of False Advisories due to the Gust Front Algorithms. The software defines a gust front as an area of convergence and then automatically labels the resultant message as a wind shear with "GAIN". Fahey et al 2002 reported that the Machine intelligent Gust Front Algorithm (MIGFA) at times failed to reinitialize, resulting in a single false message of a 95kt GAIN. In the 1st 22 months of the study there were 41 such cases. Since then, in the last 47 months, there have been 10 additional cases, indicating that the problem has diminished but is not eliminated.

Advisories of 80, 85 or 90Kt GAIN have been labeled "MIGFA or Dealiasing" and is a new category since the last study based on the assumption that MIGFA reinitialization problems may generate large but less than 95kt GAINs. The "Dealiasing" label was used for 40-75Kt GAIN.

Other software problems with the gust front algorithms appear to have continued to persist undiminished. One possible explanation is that the algorithm fails at times to correctly flag dealiased velocities near data sparse regions. This is labeled "Dealiasing" and is now the most frequent cause of False Advisories. The "Dealiasing" label was used for 40-75Kt GAIN advisories. The second most frequent cause occurred at or about sunrise. It is speculated that flocking birds leaving their overnight roosting areas produce returns on the TDWR mimicking a gust front signature. In both cases the results have been Wind Shear Alerts with a GAIN between 30kts and 90kts. Finally, there have only been 3 cases since the last study ended in January 2002 of false gust front signatures during conditions of fog/low ceilings. It is assumed that the observed weather was not the underlying cause.

4.6 LLWAS-NE++ & TDWR combined Sites

The accuracy of "Strong" "No Storm" advisories by station is shown in Figure 7. Note that of the 9 combined LLWAS-NE++ and TDWR sites only 1 site had less than 80% of the advisories deemed false, DEN–23% false. During the 69 month study period, at the other 7 combined LLWAS-NE++ and TDWR sites the percent of false alerts were: ORD-82%; STL-88%; ATL-90%; DFW & MSY-94%; TPA-95%, MCO-97% and LGA-100%. But a poor performance was not restricted to the LLWAS-NE++/TDWR combined sites. EWR, MDW and PHL were all estimated to have 100% of the "Strong" "No Storm" advisories as false.

4.7 False Advisories (< 30 knots)

In 1995 NWA concluded that "No Storms" Alerts less than 30kts were false or questionable/overstated in over 90% of the cases. As a result NWA began filtering all "No Storms" alerts less than 30kts and has not uplinked this category to NWA aircraft since that time. Although NWA researchers focused primarily on alerts of 30kts or greater in this latest study, no obvious differences have been found to convince NWA to shut off the filter.

The 6th false advisory subcategory was not a shear advisory but a "Heavy Precip" advisory which also contained the apparent contradictory observation of "No Storms" (See Figure #4). This subcategory was not identified in the 2000 study, but was identified in both the 2002 and current studies. No explanation has been proposed/identified during this study for the 88 Heavy Precip cases.

4.8 Valid Alerts (30+ knots)

The list of weather phenomena that caused the valid alerts is shown in Figure 8. This graphic indicates that over one half (229) of the valid events were associated with dry microbursts/virga, DEN accounts for 204 and SLC 25 of these valid dry microbursts/virga advisories. In addition, referring back to Figure #3, there were a total of 438 "Strong" "No Storms" valid advisories during the 69 month study period. DEN accounts for 286 of those valid alerts. In fact 54% of the "Strong" "No Storms" advisories at DEN were deemed valid. SLC is the next most accurate site with 41 valid advisories out of a total 109 for an accuracy percentage of 38%.

The detection of synoptic scale frontal systems is also of interest. While 83 valid advisories for shear associated with cold fronts were identified, there was only two valid wind shear advisories due to a warm front. This is significant for NWA in terms of the decision to continue providing warm front induced shear forecasts manually [Fahey et al, 2000].

4.9 Operational Impact

False advisories have not had a significant operational impact on the smooth and orderly flow of traffic in the ATC system. The two main reasons identified in the 2002 study for this lack of impact are still valid: 1) Since NWA is the only airline using the Send/Cancel method of TWIP distribution, flight crews at other airlines using the Request/Reply method, will most likely not request wind shear advisory information from the TWIP database during false shear events, and 2) Many dispatchers and pilots, especially at NWA, have begun to assume that alerts containing the term "No Storms" are not valid. Such an assumption, if operating into a station such as EWR, LGA, PHL or MDW would be 100% correct, but could be troublesome when operating into DEN or SLC.

5. CONCLUSIONS and RECOMENDATIONS

5.1 TWIP Wind Information Accuracy

It is important to keep in mind that, 1) "No Storms" Advisories are not as common as those where significant convection of level 3 or higher is detected; 2) the TWIP system only distributes information from the TDWR based systems. Information from the 40 LLWAS-RS and 34 WSP sites are not distributed via TWIP.

Based on FAA stats indicating that TDWR based systems are providing approximately 90% POD and 10% FAR one can conclude that the existing FAA TDWR systems at sites in a humid environment, perform very poorly when little or no precipitation is present. After removing DEN and SLC, the False Alarm rate for "Strong" "No Storm" Advisories is 80%.

"Strong" "No Storms" Humid Environment TDWR FAR=80%

Unresolved is the question: What is the POD for FAA TDWR systems at sites in a humid environment, when little or no precipitation is present? But it has been well documented for one dry environment airport, LAS. Keohan et al [2006] reports the gust front gain detection rate for the non-operational LAS TDWR at 6%, and also reports encouraging results from a 2.5-month test of LIDAR at LAS in 2005. A 68% POD performance was measured for the LIDAR and it was estimated that by adding a LIDAR MIGFA algorithm, the POD would reach approximately 91% for the gust front gain detection rate.

But the POD for FAA TDWR systems at sites in a humid environment, when there is little or no precipitation is unknown. And it would not be reasonable to suggest installation of a LIDAR based wind shear detection algorithm similar to the one being used in HKG to supplement the FAA TDWR systems at sites in a humid environment. One should also bear in mind that the LIDAR at HKG is primarily installed to detect terrain-induced wind shear in clear-air conditions – which is a location-specific application.

Assuming that the METAR evaluation method is sufficiently accurate, it is then safe to assume that the Gust Front Algorithm and specifically the dealiasing problem is the number one priority if any additional FAA resources are invested in the existing TDWR wind shear detection systems located in humid environments.

If any additional FAA resources are being deployed on TDWR, it appears that the TWIP airports with LLWAS-NE++ combined with TDWR are a close second in priority for attention. The FAR for 8 of the 9 airports, excluding DEN, is over 92%. And all 8 of these sites are located in the relatively humid, central or eastern US.

"Strong" "No Storms", Humid Environment, Merged, LLWAS-NE++& TDWR, FAR = 92%

5.2 WSP & LLWAS-RS Accuracy & Distribution

Currently, operational wind shear detection accuracy values for the WSP and LLWAS-RS systems are not available. While it is acknowledged that funding any new program is difficult, it would be in the industry's best interest to obtain operational accuracy values for these two systems. And if they are adequate, at a minimum, the WSP data should be added to the TWIP distribution system, since the communication capability already exists.

5.3 Frontal Shear Accuracy

NWA meteorology continues to distribute manually produced advisories of synoptic scale frontal induced wind shear. Additional documentation regarding the significance of the hazard to aircraft due to frontal shears, especially warm fronts is necessary. In addition a review of the thresholds used by NWA for issuance is necessary.

5.4 Hazard Distribution

The majority (approximately 80%) of NWA aircraft do not contain predictive wind shear capability. Most NWA aircraft are equipped with reactive systems. The ability to have ground based wind shear detected information, relayed to pilots and flight dispatchers as well as meteorologists is an important situational awareness benefit not only for NWA but for all operating in the US National Airspace System. In addition Air Traffic Managers at the FAA and at Airline Operation Centers can benefit from knowledge regarding current status of wind shear conditions at all major airports in the NAS.

5.5 Hazard Terminology

There is some confusion in the international aviation community regarding the terms "Wind Shear Warning"; "Wind Shear Alert" and "Wind Shear Advisory". Some additional clarification is necessary.

6. ACKNOWLEDGEMENTS

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Figure 1 Probability of Detection (POD) of HKO Windshear Alerting Service (12-month running mean values)

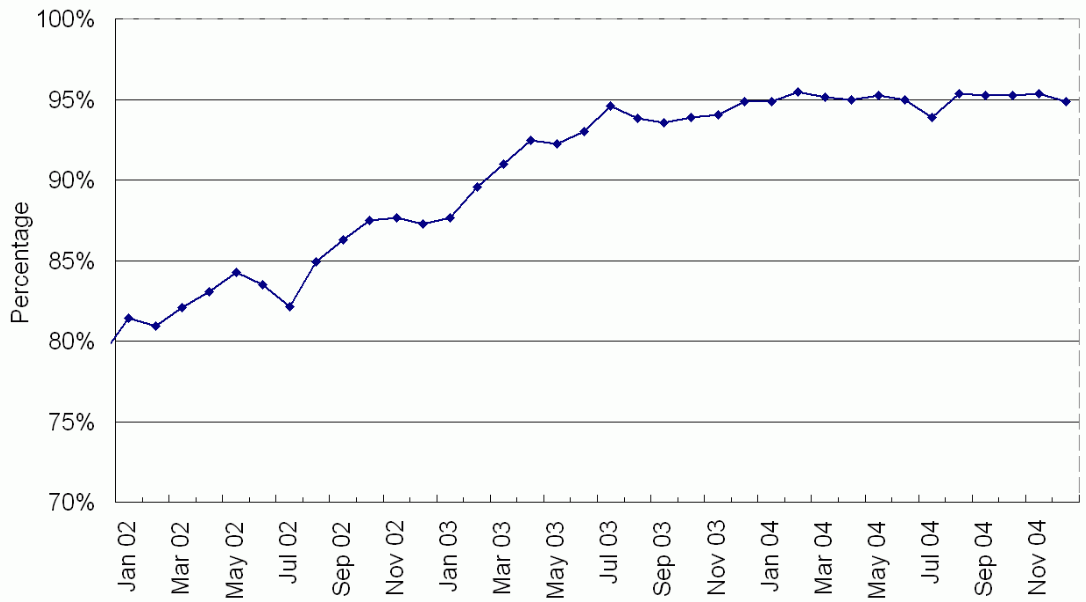
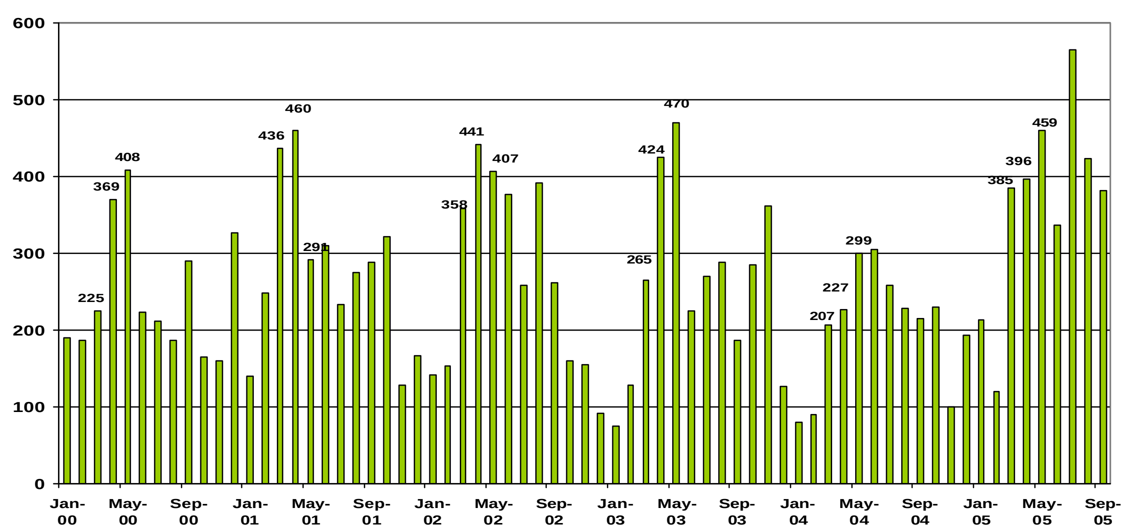


Figure 2 Total "Strong" & "No Storm" Advisories-By Month



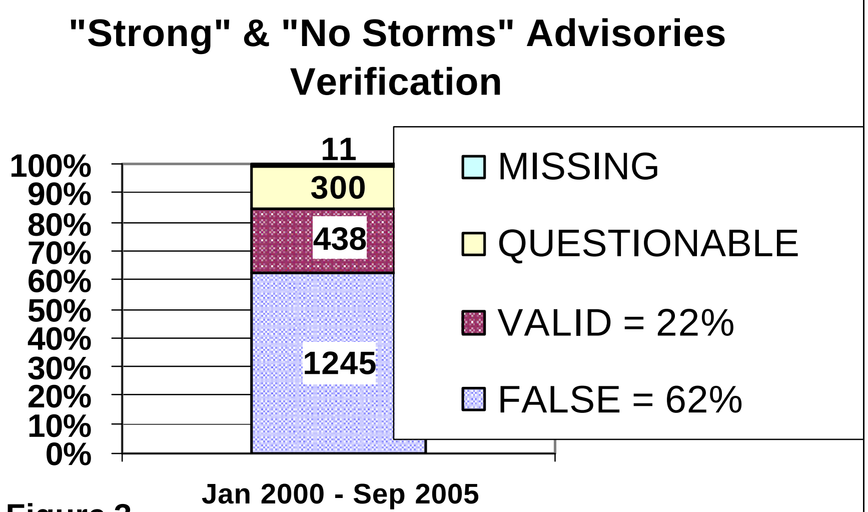


Figure 3.

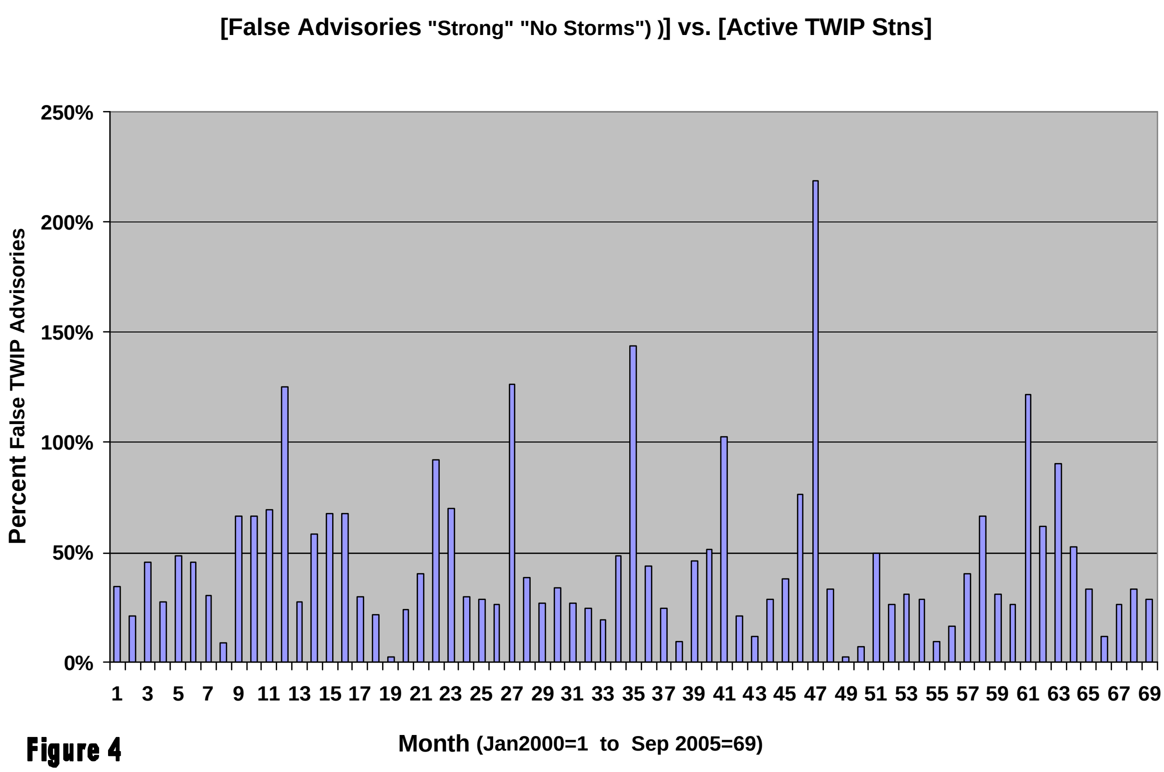


Figure 4

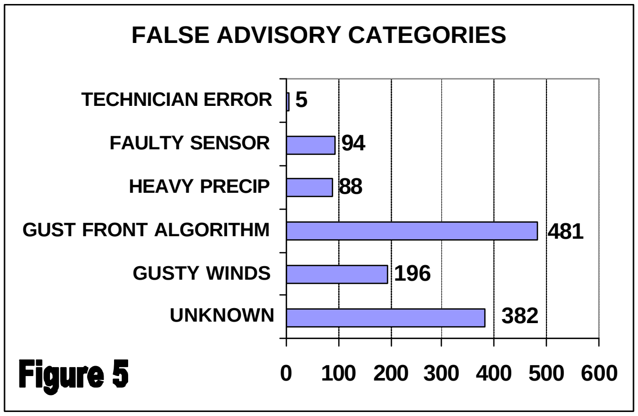


Figure 5

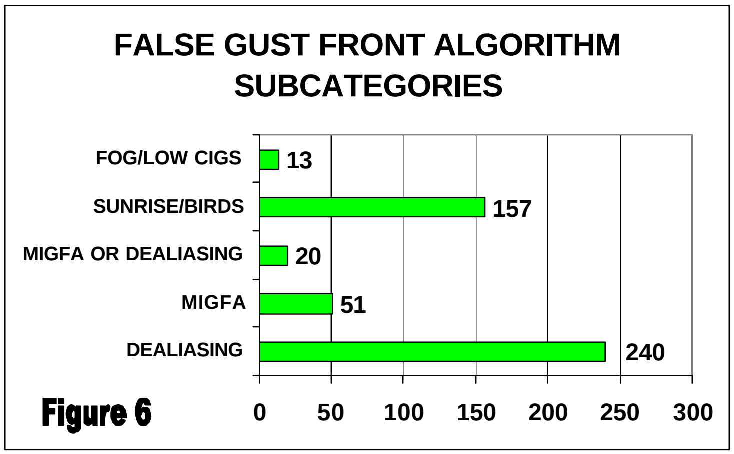


Figure 6

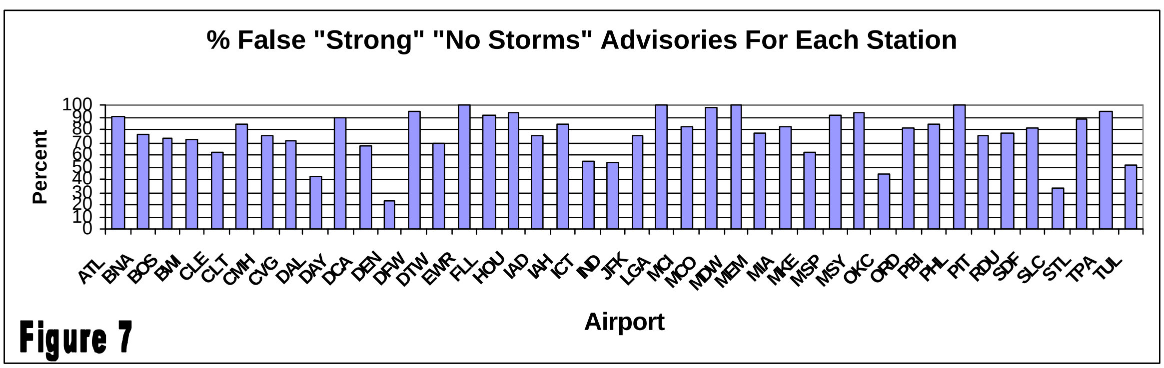


Figure 7

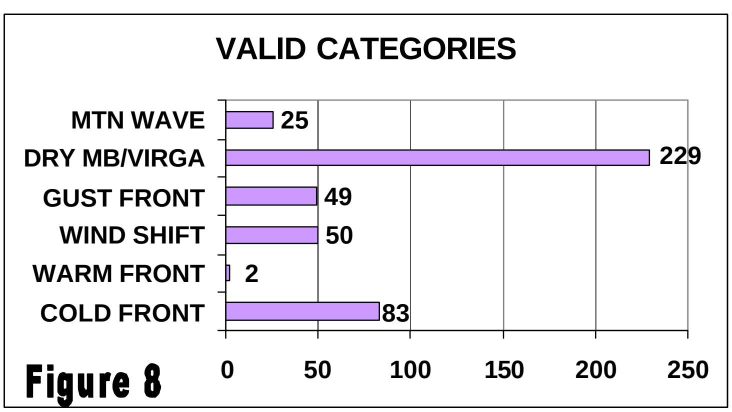


Figure 8