3.3 AIRLINE OPERATIONS CENTER USAGE OF FAA TERMINAL WEATHER INFORMATION PRODUCTS*

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1. INTRODUCTION

Adverse terminal weather is a key factor in the safety and efficiency of airline operations. Weather has been directly related to many of the air carrier accidents with fatalities in the 1990's, and the cost to airlines per year for weather delays is estimated to exceed one billion dollars(Rogers, et al., 2000), with at least half of this arising from convective weather. This paper discusses the airline operations center (AOC) use of information from the Federal Aviation Administration (FAA) terminal weather systems[1] to improve safety and operational efficiency (e.g., reduce delays and diversions, improve predictability, and airline schedule integrity) during severe or rapidly changing conditions.[2]

Historically (e.g., prior to 1992), the FAA terminal weather information capability was fairly rudimentary, and airlines had no access to the information. However, with deployment of the ITWS[3]., the ASR-9 Weather Systems Processor (WSP) production systems, and CDMnet (and perhaps Internet) product servers for ITWS and WSP airlines will have access to the products. Thus, it is important now to consider how these products could be used operationally and what refinements should be made to the ITWS/WSP products to better meet the needs of airline users.

This paper proceeds as follows: Section 2 discusses the operational experience with usage of the products from the ITWS[4] demonstration systems and then puts forth visions and issues for the AOC usage of terminal convective and ceiling/visibility products from FAA terminal weather information systems. The final section summarizes the results and suggests areas for future study.

2. AIRLINE OPERATIONS USE OF PRODUCTS FROM THE FAA TERMINAL WEATHER INFORMATION SYSTEMS (TWIS)

2.1 Usage to Date

The most extensive airline usage of an FAA TWIS has occurred with the ITWS as a result of both the product capabilities and the airline access that has been ongoing since 1994[5]. The airline operations centers have accessed the prototype ITWS information via two mechanisms:

- Dedicated situation displays (SDs) (identical to those used by FAA air traffic) at eight airline operations centers (typically used at the head dispatch desk and/or by the ATC coordinator and the airline meteorology department, where applicable). Several airlines also have used a SD in their ground operations control rooms. At several airlines, the SD images are projected on large screens viewable by everyone in the AOC.
- A WWW site which provides images of the SD terminal and 200 nmi range depictions.6 This web site also allows airlines to transfer SD images to the airline dispatch system for viewing on individual dispatcher's displays.

The real-time use by airline operations centers has identified many different decisions that have substantially benefited from ITWS information, above and beyond the weather information[7] that was already available at the AOC:

- Improving diversion/hold decisions for aircraft in flight;
- Rerouting in flight to minimize the impact of significant flight deviations (e.g., recognizing when approach gates into a terminal area will close or

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[1] We do not explicitly address the use of the National Weather Service (NWS) weather information systems, such as the NEXRAD system, that cover airports because these systems have been designed primarily as broad-area coverage sensors whose products have been designed principally to support NWS forecasters. NEXRAD in particular is quite useful in terminal decision support, and we will discuss its use by the FAA ITWS in this chapter.

[2] Weather decision support for slowly changing weather conditions is generally handled by in-house meteorological departments and/or contracted weather services using their own weather products plus those provided by the NWS.

[3] Information on the technical details of the TDWR, WSP and ITWS (including weather product technical performance) can be found in (Evans, 2000)

[4] We assume here that the reader is familiar with the products provided by the ITWS and the WSP. Descriptions of these products are available on the Worldwide Web at http://www.ll.mit.edu/AviationWeather/ and on the FAA ITWS web site: http://www.faa.gov/aua/ipt_prod/weather/itws/. The latter website also has information on the ITWS deployment schedule.

[5] Airline access to a WSP situation display did not commence until 1997 and has thus far been limited to a single airline.

[6] This web sites also provides a number of the dedicated SD capabilities such as pan, zoom, storm cell information, and the terminal winds panel.

[7] Typically NEXRAD national mosaics, NWS warnings and forecasts, and airline meteorology department products.

reopen well before the plane is at the approach gate);

- Anticipating when storm (including microburst) activity that is preventing departures will abate and providing information on the locations of microburst activity to aid in departure route selection;
- For planes that have been diverted, providing guidance on when conditions have improved enough to fly to the desired destination;
- Handling passenger and luggage transfers at hub airports;
- Improving management of ground operations (e.g., anticipating storm and lightning impacts on airport surface operations); and
- Improving coordination with the FAA on traffic flow management (TFM) programs

Below are several examples of AOC use of the Orlando ITWS demonstration system products to make operational decisions during a two-week period in 1999:

Orlando - 4 June 99

A major carrier said that they used the gust front and microburst information to advise upstream crews of what was going on at MCO. During the period of time when the thunderstorms were moving through the airport, the airline's dispatchers advised some pilots not to accept the approach clearance even if they were given one. Another major carrier said that they made three critical decisions based on ITWS. They especially liked its accuracy and timeliness when compared with the NEXRAD mosaic system they also use.

The first decision involved a DC-9 that was getting low on fuel. Based on the ITWS information, a flight diverted to Jacksonville rather than having it continue on to MCO with the likelihood of having the plane enter a holding pattern (and get dangerously low on fuel). The dispatcher used the ITWS display zoom feature to determine that Tampa was going to be an unacceptable alternative.

The second decision based on ITWS saved a diversion. Another plane was in a holding pattern north of Gainesville. The dispatcher saw that significant weather was moving off MCO and that he could break his plane out of holding rather quickly. The plane was cleared from the holding pattern in five minutes rather than 45 minutes later.

The third decision involved holding a plane on the ground in Jacksonville rather than having the crew take off and be delayed en route to MCO.

Orlando - 16 June 99

A major airline said ITWS made a big difference and made the decision to divert a flight to Tampa very easy. The weather depiction clearly showed that any attempt to get into MCO would be futile. ITWS also allowed another airline's dispatcher to inform several crews that had just pushed back from the gate that significant weather was about to hit the airport. Crews knew early on why MCO was going into holding.

Orlando - 19 June 99

A major airline used both of their two ITWS SDs intensively much of the day to make adjustments on traffic to Orlando. The ITWS data was used to divert a number of flights when it became clear the weather was not going to clear the airport.

Quantitative benefits estimates for airline savings on operations costs by use of the ITWS were accomplished by analyzing various incidents in which ITWS was used by major airlines to make decisions at Memphis, Dallas and Orlando in 1993-1994 and then scaling the benefits to account for differences in traffic counts and thunderstorm activity at the other ITWS airports. The current estimate of airline cost savings per year through airline use of the ITWS products in 1994 on a national scale is shown in table 1. It should be noted that this usage has evolved significantly in the past five years, and the current benefits are expected to be much higher.

Table 1.
National Airline Operations Costs Savings through Use of ITWS Information (as of 1994)

Decision	Operations Cost Savings per year ($M)
Fewer unnecessary diversions	28
Fewer missed connections at hub airports	6.9
Fewer periods of ramp gridlock at high-demand hub airports	0.9
Improved priority handling of key connecting flights	0.5
Fewer flights need an alternate airport assignment	< 0.1
Improved fuel estimate in marginal conditions	< 0.1
Call necessary diversions earlier	< 0.1
Less wind damage to airline property at airport	NQ
Reduced operational impact of ramp lightning periods	NQ
Shorter ramp lightning alert periods	NQ
Fewer diversions by regional airlines	NQ
NQ = No data	

2.2 A Vision for Future Airline Use of the FAA Terminal Weather Information Systems (TWIS)

Safety Enhancement

The air carrier accident with fatalities at Little Rock, AR in June 1999, together with a MIT/LL report on pilot penetrations of thunderstorms in the terminal area (Rhoda and Pawlak, 1999), have highlighted the need for better airline information on terminal weather. Airline dispatchers have regulatory responsibilities [FAA Regulation (FAR) 121.601] that include the following:

- The aircraft dispatcher shall provide the pilot in command all available current reports or information on airport conditions and irregularities of navigation facilities that may affect the safety of the flight.
- Before beginning a flight, the aircraft dispatcher shall provide the pilot in command with all available weather reports and forecasts of weather phenomena that may affect the safety of flight, including adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude wind shear, for each route to be flown and each airport to be used.
- During a flight, the aircraft dispatcher shall provide the pilot in command any additional available information of meteorological conditions (including adverse weather phenomena such as clear air turbulence, thunderstorms, and low altitude wind shear) and irregularities of facilities and services that may affect the safety of the flight.
- Additionally, the FAR states that "no PIC may allow a flight to continue toward any airport to which it has been dispatched or released, if in the opinion of the dispatcher, the flight cannot be completed safely."

Given the issues raised by the Little Rock accident, and the FAA/NASA renewed emphasis on safety enhancement, it is likely that airline access to the FAA

TWIS will be dramatically improved in the very near future. Thus, the key issues will become:

- What are the roles of AOCs, FAA controllers and data link in improving safety,
- How should the information from an FAA TWIS be structured to facilitate A OC decision making, and
- How can airlines best use the information to improve their operations.

Table 2 below summarizes the roles of the three sources of terminal information for pilots as a function of time until the plane encounters hazardous terminal weather. Since it appears from the study by (Rhoda and Pawlak, 1999) that providing information on hazardous terminal weather to a pilot well in advancement of the commencement of final approach would be more effective than relying only on messages from the control tower, we recommend that airline dispatch play a significant role in improving pilot decision making.

Table 2.
Roles of Terminal Weather Information Providers in Improving Pilot Decision Making about Hazardous Convective Terminal Weather

			Information Provider	
Time Before Accident (min.)	Plane Location	Data Link	ATC	Flight Dispatch
1-3	TRACON	Unlikely	Workload issue	No
10-20	TRACON	Yes	Need storm location, severity and motion	Unlikely on arrivals (possible on departures)
20-60	En route	Yes	No terminal Wx	Yes--need

From table 2, we see that the dispatchers can contribute significantly to safety enhancement provided that there are high-quality terminal convective weather forecasts with prediction times of 20-60 minutes. However, there is a potential problem with information overload for the individual dispatchers.

When both ITWS and WSP are operationally deployed, graphical depictions of the terminal weather will be provided for each of over 75 airports at least every five minutes. This raises the question of how individuals at an AOC could sort through this enormous information flow to determine the terminals of immediate concern (especially if there wer widespread airmass convection in a region where an airline operates into many airports). We propose that the following products should be provided by a FAA TWIS:

A. Data structures showing the spatial extent of various weather features (e.g., heavy precipitation, microbursts, icing, etc.),

B. WWW browser-viewable images, and

C. A data structure for each airport and terminal area indicating current and anticipated weather impacts (e.g., wind shear, heavy precipitation, lightning, and other hazards).

The FAA is planning to provide products A and B above as a part of the ITWS and WSP system developments. However, product C is not provided currently as a ITWS or WSP product[8], so some discussion as to why such a product would be useful is in order.

The operational concept for product C is as follows: An airline computer system could compare the airport-specific weather impact data with the current and anticipated locations of the aircraft under the control of a given dispatcher so as to generate "weather conflict probe" messages. These messages would alert an individual dispatcher to view the detailed data for specific terminals.

The mechanism for viewing the detailed data could vary from web browsers to more tailored decision support systems. Airline hub and ATC coordinators could compare the weather impact blocks with "hub push" information to determine priorities for their computer displays and the large screens in an AOC. The "weather conflict probe" messages need to be integrated with the TWIP messages and products as well.

It should be noted that the above concept for operations from product C is derived from the current Northwest Airlines use of the TDWR TWIP text product (Fahey and Bernays, 2000). Northwest parses the TWIP text message to determine whether wind shear phenomena are impacting an airport. If there are impacts at an airport, the Northwest AOC software determines if Northwest aircraft are approaching or departing that airport. If there are such aircraft, the Northwest AOC software forces a TWIP data link message up to the aircraft approaching the weather-impacted airport.

The TWIP messages only address issues associated with the airport. Information on severe weather that is moving through the transitional en route airspace and/or impacting arrival/departure transition areas is also of concern. Additionally, parsing text messages from a very short text message is a relatively inefficient means of creating the functional equivalent to product C. Rather, it seems far more efficient to explicitly address the full complement of terminal area hazardous weather and provide the information in a form suitable for AOC computer system computations.

<u>Airline Operations Efficiency Improvements</u>

Convective Weather

The above discussion has stressed the use of TWIS graphical information by an AOC for safety enhancement. There is also a need to integrate the TWIS convective information with airline internal decision support tools (DST) for collaborative decision making (CDM) and optimizing operations.

The spring 2000 program with its emphasis on multi-hour strategic collaborative planning using the Collaborative Convective Forecast Product (CCFP) (Fahey, et al., 2000; Foss, et al., 1999) has been very successful at improving the coordination between the

[8] The computations inside the ITWS and WSP TWIP product generator have intermediate products that are similar to product C.

FAA traffic flow management and routing/flight cancellation/diversion decisions by the various airlines. However, it has also become evident that the airline decision making using the CCFP must be complemented with shorter forecast products that are updated much more frequently so that unexpected convective weather can be addressed.

Figure 1 shows a contemporary example of a product that partially “fills the gap” between the 2 – 6 hour CCFP forecasts that are updated every 2 hours and the 20-minute (high accuracy) forecasts provided by the initial capability ITWS and WSP. Note that the Terminal Convective Weather Forecast product provides quantitative estimates of its accuracy (Wolfson, et al., 1999).

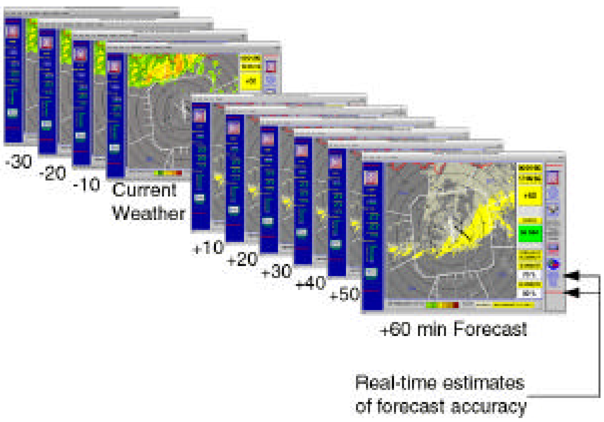

Figure 1. Current display concept for Terminal Convective Weather Forecast (TCWF). The light areas in the forecast windows (+10 to +60 min) indicate moderate and high probability of “level 3” weather (typically heavy rain). The continuous forecast loops from the past 30 minutes to the forecast time (30 or 60 min in the future). Various time subsets can be looped. Users can also select a stationary display of any forecast time. The accuracy of the forecast is continually updated in real time, based on pixel overlap criteria, and displayed as soon as it is available.

Figure 2 illustrates the type of situation where the ITWS and TCWF are essential complements to the CCFP. Clearly, weakly organized convection had occurred close to New York in a region that was not predicted to have significant convective weather coverage. Ground delays from this weather ranged from 135 minutes at Newark and 90 minutes at LaGuardia to 60 minutes at Kennedy. In such situations, AOCs must rapidly develop plans to cope with the weather that has developed to reduce the impact on planes traveling to and from the major terminal area.

To illustrate the issues that arise in tailoring the FAA TWIS products for AOC operations, we consider the airline operations decision support tools (DSTs) that might be called into play when a squall line is approaching a major hub from the west as illustrated in figure 2. An airline operations DST would need to address:

- Routing for flights to and from the west around the squall line to reach the west arrival and departure fixes into the terminal area,
- Routing for flights to and from the west to reach the east arrival and departure fixes into the terminal area when it is no longer feasible to use the west arrival and departure fixes into the terminal area,
- Determining when routing for flights to and from the west should resume using the west arrival fixes into the terminal area so that the arriving aircraft can arrive at the airport on the optimal paths once the weather has moved to the east of the airport, and
- The corresponding issues for flights arriving or departing to the east.
- Whether to file for routes through the squall line rather than flying around the ends of the squall line, with the expectation that the route through the squall line may change as the aircraft is nearing it.[9]

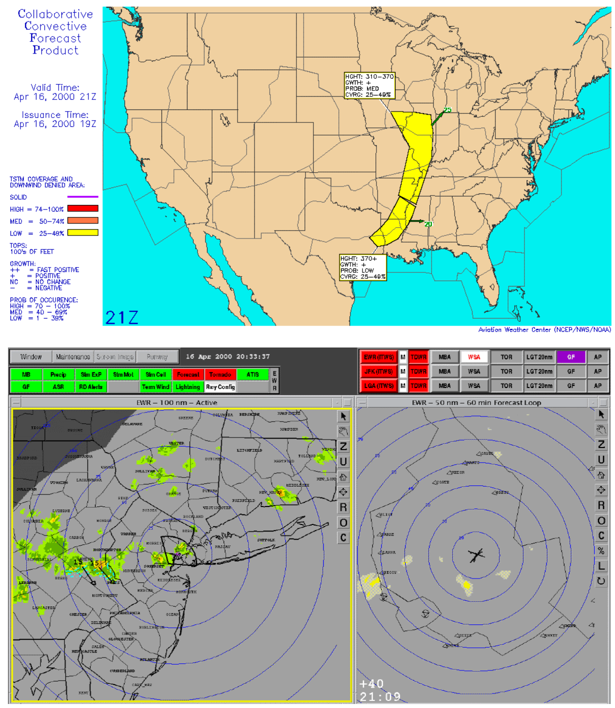

Figure 2. Comparison of CCFP forecast for 21 Z issued at 19Z (top) with ITWS situation display at 2033 Z (bottom left) and TCWF predicted storm positions for 2103Z issued at 2033 Z (bottom right) for New York on 4/16/00.

Since routing flights around a squall line and/or to distant arrival and departure fixes will result in flight times that are significantly greater than when the weather is fair, it may be necessary to invoke other DSTs that will address optimization for hub connections, aircraft, and flight personnel management.

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[9] A key element of the CDM use of the CCFP has been the allocation of capacity around the ends of squall lines. However, as a squall line nears a major terminal area, there can be a very high penalty in terms of distance flown to fly around the ends of the squall line. In such cases, flying through gaps in the squall line can be quite advantageous. Operationally, achieving the flexibility to take advantage of changes in the convective weather will also require corresponding decision support tools for the FAA traffic flow managers and controllers (e.g., DSTs such as CRCT and “direct-to”).

The capacity loss which occurs when the squall line moves over the hub airport may invoke National Airspace System (NAS) CDM adjustments to the schedules for flights scheduled to arrive after the weather impact on the terminal area has ended. Additionally, if the loss of arrival and departure fixes on one side or the other of the terminal area associated with the hub airport results in a terminal area capacity less than the scheduled number of operations into the hub, then additional CDM decisions may need to be addressed.

One of the important factors in creating airline operations DSTs for the situation discussed above is the estimation of probable flight times for the various aircraft. This in turn necessitates a time varying projection for the available paths to and from the terminal area, which in turn requires careful judgement as to the paths that the airline's pilots would find acceptable. The quantitative results on pilot deviations around weather at a major hub airport discussed by Rhoda and Pawlak (1999) may be helpful as an aid to the airline dispatch and ATC coordinators in making this important determination.

This area of airline operations center integration of the information from ITWS/WSP/TCWF with information from the FAA/airline "strategic" traffic flow management process using the CCFP is just beginning. There are issues to be resolved both on the FAA side and for the airline dispatch operational concept. An important issue for the airlines will be the FAA allocation of decision making responsibilities for traffic flow management between the Command Center, en route TMU's, and the traffic management coordinators at major terminal areas as a function of prediction time. At long prediction times (e.g., greater than 2 hours), the Command Center will probably be the lead organization. For very short traffic flow decision lead times (e.g., < 5 minutes), decisions probably will have to be made at the terminal area level. However, the allocation of responsibilities and the corresponding operational concept for traffic flow management and CDM for prediction times between 5 minutes and 2 hours is not clear.

The accuracy of convective weather forecasts degrades significantly as the prediction time increases from 5 mins to 120 minutes. For the foreseeable future, accurate "pin point" predictions of convective weather impacts at the spatial scale of airport runways will be difficult to achieve in many cases for prediction times > 20-30 minutes. Hence, probabilistic forecasts will probably be necessary.

The operational concept for airline use of probabilistic convective terminal products such as TCWF is just beginning to evolve. The TCWF has been provided to the airlines operationally since 1999, with a strawman integrated ITWS/TCWF display being demonstrated in the summer of 2000 (Theriault, et al., 2000). The TCWF product also has been available as Web-browser-viewable images on the ITWS demonstration Internet and CDMnet servers (Maloney, 2000). However, it has not been integrated as yet into the airline dispatch DSTs, and it is not likely that the airlines will expend funding to accomplish this integration until the FAA makes a decision on whether the TCWF will become a part of the ITWS product suite.

Use of Information on Ceiling/Visibility and Winds

The CDM program has emphasized the collaborative interactions between the airlines and the FAA to optimize the use of the available capacity when the demand exceeds available capacity.

Non-convective terminal weather (e.g., low ceilings/visibility and adverse winds) are major constraints on terminal capacity. For example, a recent study of delays at Newark International Airport (EWR) (Allan and Gaddy, 2000) found that convective weather accounted for about 37% of the delays, low ceiling/visibility for 35%, high winds 13%, with the remainder of the delays due to volume or cause not determinable.

Thus, it is important for the AOC's to obtain the information from FAA TWIS that will help the airlines plan to minimize the adverse impact of capacity restrictions on low ceiling/visibility and high winds capacity. The airlines will need to develop contingency plans that may entail flight cancellations and delay allocation to minimize the overall adverse impact on airline operations. The expectation is that the TWIS forecasts for ceiling and visibility may well be probabilistic in nature (see, for example, Wilson and Clark, 2000). For example, near-term operational CWSU users of a ceiling/visibility product may have little interest in a predicted distribution function for the capacity as a function of time. Rather, they may prefer a single "best guess" time for capacity changes with a subjective statement of the uncertainity in the "best guess" time.

An airline has many more decisions in a low ceiling/visibility situation than the CWSU/TMU traffic managers:

- Should some planes request clearance to an intermediate airborne location where they may hold, with the expectation of arriving earlier than if they held the full expected time on the ground (e.g., as has been done over Crescent City, OR for flights to SFO)?
- Which flights may need to be cancelled due to excessive expected delays or to open up a slot for a higher priority flight?
- Should the order in which flights that will operate into or out of a weather-impacted airport be changed to minimize overall disruption in airline operations?

Since the cost function associated with these various decisions clearly varies significantly between different airlines operating into a weather impacted airport, there will need to be a more complete probabilistic characterization of the weather information to support the airline decision making than is the case for the FAA use. Fortunately, the airlines already are quite experienced at developing decision support tools that use probabilistic information (e.g., in the development of yield management systems and flight scheduling).

3. SUMMARY

Terminal weather is a critical factor in airline operations. Both the content of the FAA TWIS products, the number of terminal areas with a TWIS, and airline access to the TWIS information will dramatically increase in the very near future. The operational experience with providing ITWS information to airlines since 1994 has demonstrated substantial improvements in safety as well as substantive benefits to the airlines and their passengers through AOC usage of these FAA system products.

Airlines will need to develop decision support tools to tailor the FAA weather products for airline decision making. We have outlined some concrete examples of near-term applications. The collaborative development of an integrated FAA/airline terminal weather decision support system to address both safety and efficiency needs will clearly be an important element of air traffic management system development for a number of years to come.

We would particularly call attention to the need for much greater collaboration in the products generated by the FAA TWIS. The FAA wind shear warning system development benefited significantly from input provided by the TDWR/LLWAS users group which had representatives from the FAA, airlines, pilot unions, and R&D groups. Thus far, the new generation of FAA terminal weather information systems (e.g., ITWS and WARP) had FAA-only users groups. In view of the safety and efficiency benefits to the NAS which can accrue from AOC use of the ITWS and WSP products, it may be desirable to have a joint FAA, airline, pilot, and dispatcher users group for the development and refinement of the FAA terminal weather information systems.

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