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Baseline Assessment of the Use of Weather Information in Airline Systems Operations Centers

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Final Report

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16. Abstract <p>A study was conducted to establish current (baseline) practices in the use of weather information at Airline Operations Centers (AOCs). Two large airlines with substantial international service, one smaller airline with national service, and a small regional airline were included in the study. Dispatchers were interviewed at each airline and asked to assign priorities to listed weather factors. Responses were similar across airlines, but dispatchers from the larger long-haul airlines gave somewhat higher priorities to some of the Wind factors. There were numerous differences between the priorities assigned by dispatchers and those assigned by pilots, especially during the planning phase, with small but consistent internal differences in ratings among pilots between Part 91 pilots and Part 121 pilots. The operators interviewed all expected to continue using dispatchers and weather personnel in the AOCs as integrators and flight planners/followers, expecting that the increased networking and availability of new sources of weather data envisioned in the NextGen environment would enhance their ability to make more accurate assessments of operational issues. It was deemed critical that the NextGen environment continue to provide the information currently deemed central to allowing the dispatcher-pilot team to deal effectively with diversions. Several recommendations are included for improving the structure and functioning of the weather-information environment.</p>					
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LIST OF ACRONYMS/ABBREVIATIONS USED IN THIS REPORT

Acronym/ Abbreviation	Definition
ADDS -----	Aviation Digital Data Service
AGL-----	Above Ground Level
AIRMET -----	Airmen's Meteorological Information
AOC -----	Airline Operations Center
ATC-----	Air Traffic Control
AV charts-----	Aviation weather charts
CCFP-----	Collaborative Convective Forecast Product
DoD -----	Department of Defense
EAG-----	European Aeronautical Group
FAA -----	Federal Aviation Administration
FAR -----	Federal Aviation Regulations
FBO-----	Fixed-Base Operator
GA -----	General Aviation (Part 91 operations)
GFF-----	Graphical Flight Following
IFR-----	Instrument Flight Rules
ILS -----	Instrument Landing System
LAMP -----	Localized Aviation MOS (Model Output Statistics) Program
MEL -----	Minimum Equipment List
METAR -----	Aviation Routine Weather Report (from <i>MÉTéorologique Aviation Régulière</i>)
NAS-----	National Airspace System
NEXRAD -----	NEXt Generation Weather RADar
NextGen -----	Next Generation Air Traffic System
NNEW-----	NextGen Network-Enabled Weather
NOAA-----	National Oceanic and Atmospheric Administration
NOTAM -----	Notice to Airmen
NOWrad -----	National Operational Weather radar
NWS-----	National Weather Service
QICP -----	Qualified Internet Communications Provider
SIGMET -----	Significant Meteorological Information
TAF -----	Terminal Aerodrome Forecast
TFR-----	Temporary Flight Restrictions
VHF -----	Very High Frequency
WIDS-----	Weather Information Display System
WSI -----	Weather Services International

EXECUTIVE SUMMARY

Approximately 70 % of National Airspace System (NAS) delays are attributed to adverse weather conditions (Leader, 2007). The Next Generation Air Traffic System (NextGen) has the goal of reducing weather-related delays by at least 50 % (Leader, 2007). This report is intended to help understand the potential effect of changes in the NAS on the way weather information is conveyed to stakeholders in the airline industry. Using interviews and questionnaires, we evaluated the procedures, products, priorities, and communication methods operative in airline operations centers (AOCs) to collect, analyze, summarize, and disseminate weather information. The goal was to characterize the current situation in the industry as a baseline and to consider the potential impact of changes anticipated with the NextGen environment.

Four airlines were included in the study, two large operators with substantial international service, one smaller operator with national service, and a small regional operator. Although the general procedures and goals were very similar across the various AOCs included in the study, there were several differences in the specific weather products being used and in the extent to which individual airlines created their own software systems for the use by dispatchers and meteorologists.

Dispatchers from the four airlines gave very similar ratings of priority across most of the weather factors. The only differences of note were that dispatchers from the large, long-haul airlines gave somewhat higher priorities to some of the Wind factors. This may have resulted from the greater flexibility in route planning and route changing associated with longer flights; greater distances allow for more significant diversions to cope with the safety, efficiency, and comfort issues associated with the category Motion of the Air. There were numerous differences between the priorities assigned by dispatchers as compared with those assigned by pilots, especially during the planning phase, and there were very small but consistent differences between ratings by those pilots engaged in Part 91 operations and those engaged in Part 121 operations.

Airline Operations Centers followed well-developed procedures for collecting, analyzing, and communicating weather data. While there were small differences among the airlines, they all consulted several information sources to develop a picture of weather relevant to their flights. The larger operators developed products of their own, often based on data delivered from a commercial source of weather information. In all cases, pilots received weather information regarding their flights compiled by dispatchers. With the depth of the preparation in flight planning and the responsiveness of dispatchers to changes in weather, pilots were operating under the continual guidance of dispatchers. The operators interviewed agreed that they expected to continue to use dispatchers and weather personnel in their AOCs as integrators and flight planners/followers, providing information to the flight crews, with the expectation that the increased networking and availability of new sources of weather data envisioned in the NextGen environment would enhance their ability to make more accurate assessments of operational issues. The operators considered it critical that the NextGen environment continue to provide the information currently rated as necessary to allow the dispatcher-pilot team to deal effectively with diversions.

There are a number of ways to improve the delivery of weather information, the structure of the dispatcher's working environment, and decision support tools for dispatchers. Those recommended include:

- Standardizing the method used to achieve QICP designation for new Internet-based weather products
- Displaying weather data together in the 5 identified main clusters
- Improving AOC-ATC communications by using decision-support tools and 4-D flight models to match weather forecast time points
- Prioritizing displayed weather information according to relative importance by 3 phases of flight for pilots and 2 phases of flight for dispatchers

BASELINE ASSESSMENT OF THE USE OF WEATHER INFORMATION IN AIRLINE SYSTEMS OPERATIONS CENTERS

BACKGROUND

Approximately 70 % of National Airspace System (NAS) delays are attributed to weather (Leader, 2007). The Next Generation Air Traffic System (NextGen), an envisioned NAS future environment providing information to pilots, dispatchers and controllers, has the goal of reducing weather-related delays by at least 50 % (Leader, 2007). An important part of the effort is to integrate disparate weather data so that information can be shared among all NextGen users. It is important, however, to ensure that NextGen provides the specific weather information that the Airline Operations Center (AOC) personnel require to plan and follow flights. Although the AOC includes many functions, such as supervisors, coordinators, and meteorologists, the majority are dispatchers. As a result, to simplify exposition we will use the term *dispatcher* to refer to our research participants, even though they often included other professional.

Purpose of the Research

As a first step in specifying the weather information that should be provided in the NextGen environment, this research was intended to provide baseline information about:

- The weather products that AOCs use now and the tasks for which they are used
- Which products have been replaced recently, which products took their place, and which products are being considered for future replacement
- The priorities of weather information elements for flight planning/replanning and flight following
- Gaps between product capabilities and information needs
- How the weather information and presentation needs of pilots differ from those of AOC personnel

General Approach

The approach to accomplishing these goals entailed two components. The first task involved identifying important weather factors and collecting ratings of weather information importance via an Internet-based survey. The second task used interviews and observations in context at AOCs to determine current practices and the similarities and differences across different airlines.

TASK 1: WEATHER FACTORS AND PRIORITIES

Several studies have identified important weather factors in aviation (Beringer & Schvaneveldt, 2002; Comerford, 2004; Heuwinkel, 1993; Krozel, Capozzi, Andre, & Smith, 2003). Two of these (Beringer & Schvaneveldt, 2002; Heuwinkel, 1993) have also identified priorities associated with the factors. Schvaneveldt, Branaghan, Lamonica, and Beringer (2008) reviewed these studies and selected the factors shown in Figure 1 as representative of the weather factors identified in all of the studies. These factors were included in the priority ratings obtained in the present investigation.

Method

The number of dispatchers providing ratings from each airline was 19, 41, 5, and 18 for the four airlines, respectively. A total of 48 individuals did not complete two or more ratings, and five others gave the same rating to everything. The data from these 53 participants are not included. A website, Survs.com, was used to collect the priority rating data. Participants accessed the survey via a link sent in an invitation email. The survey presented an introductory page providing an overview of the study and estimating the time it would take to complete. Next, the software displayed instructions for how to complete the survey and a demographic questionnaire. Participants then rated the importance of each information element for the activities of flight planning and flight following on a 4 point scale, with 1 representing least important and 4 representing most important. Completion took approximately 10 minutes. Data collection took place over a three-month period. The importance ratings were converted to priorities by subtracting them from 5. Thus, 1 becomes the highest priority and 4 is the lowest.

The pilot data for Part 91 General Aviation (GA) operations were obtained by and reported in Schvaneveldt, et al. (2008) using a methodology developed by Schvaneveldt, Beringer, and Lamonica (2001) and are included for comparison. The Part 121 pilot data were collected from 16 pilots, flying for a regional carrier, as part of another study. The participants were informed of the opportunity to participate in the study by the airline and the by pilots' union. All participants were compensated for their time.

Table 1. Median priority ratings for dispatchers by airline and collectively and for pilots by operations category (1 is highest priority)

Weather Factor	Planning							Flight Following						
	Dispatchers by Airline # / Median across airlines					Pilots		Dispatchers by Airline # / Median across airlines					Pilots	
	1	2	3	4	M	Part 91	Part 121	1	2	3	4	M	Part 91	Part 121
Barometric Pressure	3	3	3	3	3	1	3	3	3	4	3	3	1	2
Clouds/Ceiling	1	1	1	1	1	1	2	1	2	2	1	1.5	1	2
Clouds/Coverage	1	1	1	1.5	1	4	3	1	2	2	2	2	3	2
Clouds/Tops	2	2	2	2	2	2	3	2	2	1	2	2	2	2
Clouds/Types	2	3	2	2	2	2	2	2	2	2	2	2	2	2
Density Altitude	3	3	3	2	3	1	2	2	3	4	3	3	1	2
Front Location and Type	1	2	2	2	2	1	2	1	2	2	2	2	1	2
Precipitation (Ice, Freezing Rain, Sleet)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Precipitation (Rain)	1	2	1	2	1.5	3	2	1	2	2	2	2	2	2
Precipitation (Snow)	1	1	1	1	1	3	2	1	1	2	1	1	1	2
Present/Forecast Temp.	2	2	2	2	2	1	2	2	3	3	2	2.5	1	2
Runway Conditions	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Thunderstorms/ Hail/Lightning	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vertical Temp. Gradient	3	3	3	3	3	3	3	3	3	3	3	3	4	3
Visibility	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Visibility/Fog (Dew Point)	1	1	1	1	1	1	2	1	1	1	1	1	1	1
Visibility/Haze	1	2	1	1	1	1	2	1	2	2	1	1.5	1	2
Visibility/Sand/Dust/Ash	1	1	1	1	1	3	2	1	1	2	1	1	1	1
Wind/Clear Air Turbulence	1	1	2	1.5	1.25	3	2	1	1	1	1	1	1	2
Wind/Down Draft	1	1	2	1.5	1.25	4	2	1	1	1	1	1	1	1
Wind/Gusts	1	1	2	1.5	1.25	3	2	1	1	2	1.5	1.25	1	2
Wind/Hurricanes	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wind/Mountain Rotors	1	1	2	1.5	1.25	3	1	1	1	2	2	1.5	1	1
Wind/Surface Winds	1	1	1	1.5	1	3	2	1	1	2	1.5	1.25	1	1
Wind/Tornadoes	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wind/Wake Vortices	2	2	2	1	2	4	2	3	2	2	2	2	1	1
Wind/Winds Aloft	1	1	2	2	1.5	1	2	2	1	2	1.5	1.75	2	3
Wind/Windshear	1	1	1	1	1	4	1	1	1	1	1	1	1	1

Altitude, and Temperature), pilots gave higher priorities than did dispatchers. These factors change frequently, and pilots often obtain these values from air-traffic controllers or from calculation. Dispatchers did not give these factors priority during flight.

Only two of the 13 differences found for the planning phase showed pilots assigning higher priority, and these were for Barometric Pressure and Density Altitude. These factors critically affect take-off and landing performance so planning decisions relating to runway length and aircraft weight would be of concern to the pilot. Dispatchers may assume that pilots obtain this information from local sources.

Many of the discrepancies between the priority ratings obtained from pilots and those obtained from dispatchers for the planning phase may occur because the dispatchers are planning for the pilots while the pilots are planning for themselves. To illustrate this point, pilots may delay decisions about factors that can easily change between the time of planning and the time of flight so these are rated as less important. This is certainly true of some of the *Wind Factors*, *Cloud Coverage*, and *Visibility due to Sand, Dust, or Ash*. Dispatchers also give higher priority to *Rain* and *Snow* in planning than did pilots. Dispatchers are planning to achieve safety, efficiency, and comfort a priori, so they must first consider all of the factors that could affect the route and timing of the flight. The GA pilot may deal with many of these details subsequent to planning, partly because of greater flexibility in the timing and execution of the flight.

It is worth noting that there was some reasonable agreement between dispatchers and Part 121 pilots (correlations shown in Table 2), but the departures from a perfect correlation highlight the fact that dispatchers and pilots require somewhat different information. This can be seen in the fact that pilots require slightly different information between flight planning and flight following, whereas dispatchers appear to require much of the same information across the two phases. This might suggest that in-flight weather information systems designed for the pilot could layer information, placing the most critical information on the top layer of the display/system with the less critical information in a sublayer.

Table 2. Priority-rating correlation coefficients between Part 121 pilots and dispatchers by activity phases.

		Planning		Flight Following	
		Dispatcher	Pilot (121)	Dispatcher	Pilot (121)
Planning	Dispatcher	-			
	Pilot (121)	0.58	-		
Flight Following	Dispatcher	0.92	0.69	-	
	Pilot (121)	0.55	0.71	0.64	-

This assessment of preferences should be compared with those reported by Heuwinkel (1993) for users other than pilots (comparison of the Heuwinkel data with more recent pilot ratings appears in a companion report; Schvaneveldt, Branaghan, Lamonica, and Beringer, in review). Given that the Heuwinkel document is difficult to find, we have reproduced the six summary tables/figures from that report in the Appendix (Figures A1 through A6).

Direct comparisons by weather item are difficult inasmuch as the categories are slightly different between Heuwinkel and the present assessment and the rating schemes were different (“High,” “Medium,” and “Low priority” in Heuwinkel versus “critical,” “important,” “relevant,” and “irrelevant.”). Suffice it to say, however, that one can gather some of the specific headings in the Heuwinkel data in larger overarching categories. As an example, Heuwinkel reports ratings of “Volcanic Ash,” “Widespread Low Visibility,” “Surface Visibility,” “Runway Visual Range,” and “Inflight Visibility,” whereas the present assessment used “Visibility,” “Visibility (Fog),” “Visibility/haze,” “Visibility/Sand Dust/Ash” as categories. For the Heuwinkel data, all of the five visibility categories (one is both visibility and potential engine-ingestion hazard) were rated as high priority. In the present data, all four categories related to visibility were rated at 2 or above (only Part 91 pilots gave a median rating of 3 to Sand/Dust/Ash for the planning phase), and thus visibility-factor ratings appear consistent between the 1993 data and current data. A similar pattern emerges if one groups other factors in ways that allow for a meaningful comparison. Thus, those factors that were rated of high importance in the 1993 assessment continue to be rated as highly important factors today.

TASK 2: AOC INTERVIEWS IN CONTEXT

In Task 2, we conducted in-depth interviews at four AOCs to determine the procedures, products, and communication methods used to collect, analyze, summarize, and disseminate weather information presently being used and how it is being used.

Table 3. Demographic information for the participating carriers

Interview Participants	Fleet Size	Aircraft Models	Flights per Week	Route Length (hrs) Avg / min / max	Geographic Service	Weather Products
Coordinator Manager 4 dispatchers	604	Boeing 777 757 737-800 MD 82/83 A300/600	13,650	4.5h / 1h / 16h	Worldwide	Sabre WSI Pilotbrief EAG WSI Fusion NEXRAD, Convective SIGMETs, AIRMETs NOAA weather Center Java Tool
International Senior Meteorologist Dispatcher	1,023	Boeing 747 737-700 737-800 757-200 767-300 767-300ER 767-400ER 777-200ER 777-200LR MD 88, 90	26,000	4.5h/ 1h/ 16h	Worldwide	WSI Contract with WSI two meteorologists onsite, Turbulence chart (provided for every city) Jeppesen NWS Surface chart / GFS model (500 millibar)
Director Manager 4 dispatchers	51	Airbus 318 319 320	2,000	2 h / 1h / 5h	Mostly mainland US. Seasonal to Alaska	Sabre WSI A V Charts, Thunderstorm/tornado Watch Boxes, Thunderstorm probability, Severe weather conditions, Lifted / K index Aviation Terminal Forecast, TAFs CCFP
Dispatch Supervisor	163	Bombardier CRJ100/200 CRJ700 CRJ900 Dash 8-200 Embraer ERJ 145	5,600	2h / 1h / 16h	Mainland United States and Hawaii	Flight Explorer AIRMETs, SIGMETs, Frontal boundaries, Radar, clouds/ceiling Sabre TAFs, METARs, NOTAMs, AIRMETs WSI winds aloft

Method

Table 3 summarizes characteristics of the participating airlines, including the weather products used. Four AOCs served as participating facilities. Two served large airlines with worldwide operations. One smaller operation had only national service, and another small airline had only regional operations.

We contacted each airline and identified a principal contact for each investigation. Then we arranged times to interview and observe dispatchers. The interviewer

began by identifying each procedure used to gather weather data, as well as the sources and forms of data used in flight planning and flight following. Typically, the sources included the method of delivery (Internet, satellite radio, VHF Broadcast, etc.), the information provider, and the specific product used.

Then the interviewer explored the information dispatchers' needs or wants, and whether they had access to that information at present.

After interviewing, we observed the dispatchers to determine, through various examples, which weather factors were utilized, as well as the source, form, and method of delivery for each factor. The observations served to confirm and extend the data obtained from the interviews.

Results

We begin by describing the dispatcher's work. Through observation and interview we uncovered the process shown in Figure 2.

- Dispatchers conduct the following activities (Heuwinkel, 1993)
- Develop and file flight plan
- Gather weather information
- Provide weather information to the pilot
- Respond to pilot requests for weather information and rerouting
- Distribute information on changing weather to the pilot
- Reroute aircraft
- Develop strategic flight schemes for group of flights according to weather conditions

Broadly, dispatch involves two components: flight planning and flight following. Flight planning occupies the most time and is proactive in nature. Flight following is usually uneventful but can also be the most critical and time-compressed activity. This is especially true when unexpected weather occurs. In such situations, dispatchers need to make decisions quickly, taking into account the location of the airplane, proximity to various airports, details about the airports, airplane configuration, and fuel status. Further, because weather can be geographically broad, it may affect many aircraft at the same time.

Flight Planning. The first step in flight planning is to determine if the flight will need a takeoff (return) alternate. Given that airplanes require better weather and visibility to land than to takeoff, if a plane takes off in reduced visibility and then must land quickly, it may need to land at a close airport with better weather conditions. This airport is called the *takeoff alternate*.

To investigate whether a takeoff alternate is needed, the dispatcher uses a Dispatch program. The Sabre Dispatch Manager is an example of this. The dispatcher uses this program to examine METARs and TAFs. Additionally, they inspect a weather map program (Flight Explorer is a common example) to determine if adverse weather is headed toward the departure airport. Finally, they inspect NOTAMs to determine if there are problems at the departure airport that would preclude a safe landing. One example of this would be an out-of-service

ILS. If any one of these information sources indicates a potential problem with making an emergency landing at the departure airport, then the dispatcher will choose a takeoff alternate.

If a takeoff alternate is needed, the dispatcher investigates appropriate airports using the Dispatch Monitoring System.

Generally, an alternate is evaluated according to the following criteria:

- Proximity to the departure airport
- Absence of adverse weather (to investigate weather, they examine METARs and a weather map program for the potential alternate)

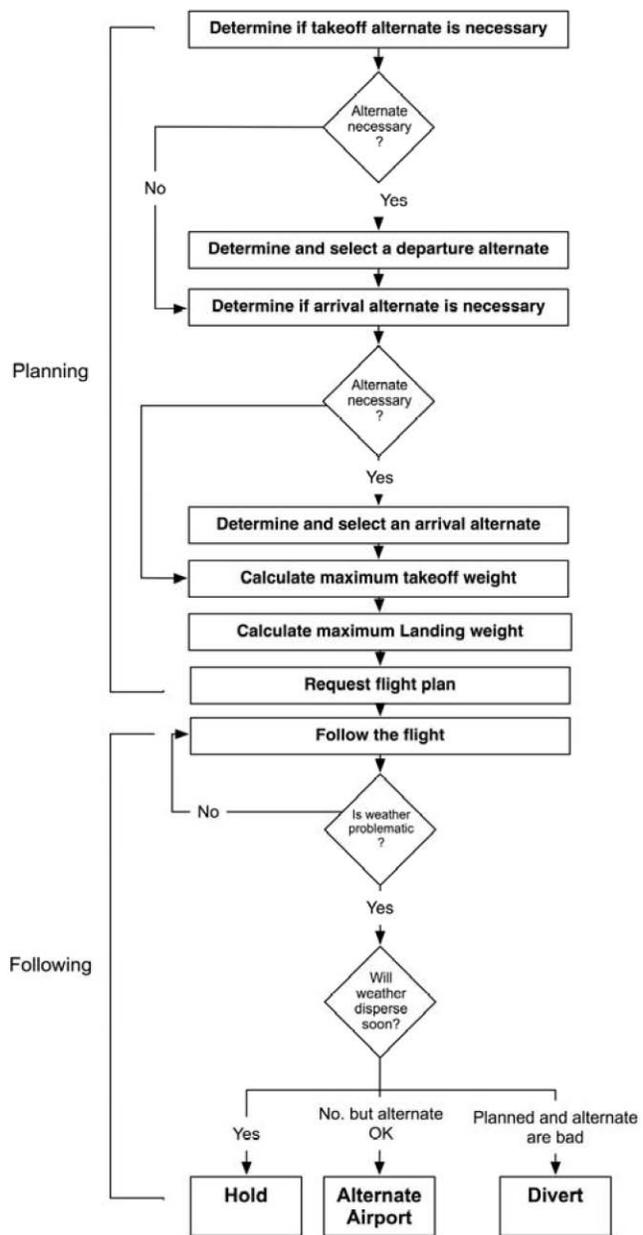


Figure 2. A Generalized View of the Dispatch Process

- Availability of fuel/FBO
- Runway suitability
- Availability of contract maintenance

Next, dispatchers turn their attention to the arrival airport. In this case, the dispatcher determines if an arrival alternate is needed. By FAA regulation, an alternate must be available if visibility is less than 3 miles or if the ceiling is below 2,000 feet AGL.

Dispatchers examine METARs, TAFs, and NOTAMs for the vicinity of the arrival airport. They check the validity of the METARs by comparing the last 3 hours' METARs to the current forecast. And, finally, they examine the weather map program for weather in the destination city.

Evaluating the arrival airport alternate is similar to evaluating the departure alternate. Criteria include:

- Proximity to the flight's current route
- Proximity to the arrival airport
- Absence of adverse weather conditions at the alternate airport (using METARs, TAFs, and the weather map program)
- Airport typically served by carrier
- Availability of fuel/FBO
- Runway suitability
- Availability of contracted maintenance

The dispatcher next uses the dispatch monitoring program to check for MELs (Minimum Equipment Lists) to identify maintenance issues associated with the airplane. For example, if the windshield wipers are inoperative, the dispatcher must choose an alternate airport at which there is no precipitation. Once an alternate is chosen, the dispatch monitoring program calculates how much extra fuel to include and whether the airline needs to cut back on payload.

After alternates have been chosen (if necessary), the dispatcher uses dispatch monitoring to calculate the maximum takeoff and landing weights. This function takes into account runway length, temperature, barometric pressure, anti-icing equipment (which uses substantial power), anti-skid equipment, and the like. Once calculated, the dispatcher ensures that these fit with the runways chosen for the departure and arrival airports, as well as their alternates.

The final activity in flight planning is requesting the flight plan. By examining the weather map program, the dispatcher chooses a route in the dispatch monitoring system that avoids any adverse weather that is likely to impact the flight. Once chosen, the dispatcher submits the flight plan. This creates the ATC strip and sends the release for printing. This is the paperwork that the pilot receives.

Flight Following. Generally, the process of flight following entails looking for changes. The dispatchers track the METARs, TAFs, and weather map looking for deviations from the forecast. For each flight, they can use the weather map program to determine if adverse weather is developing along the way. Also, an alert on the dispatch monitor indicates when a special METARs, signifying changes in weather from the original flight plan, has been issued. In such a case, the dispatcher examines METARs and the weather map program to determine if the adverse weather is likely to disperse soon. If so, the dispatcher asks the pilot to hold for a while before attempting to land. If the adverse weather is not likely to disperse, the dispatcher advises the pilot to proceed to the alternate airport. Finally, if the alternate also has adverse weather, the dispatcher suggests a diversion to a different airport. This requires all of the steps involved in determining an arrival alternative outlined above.

Next, we describe each airline and the products they use. Although all airlines have idiosyncrasies, each uses some variation of this generalized process described above. Note that for all of the products described, most, if not all, weather information originates with the National Weather Service (NWS), which now provides AIRMETS, SIGMETs, and other information in graphical reports. All products that dispatchers use must be authorized by the FAA.

Airline 1

The first AOC served a large airline with operations worldwide. Figure 3 shows a part of the operations center. This airline uses multiple tools for weather-information delivery.

The various tools include:

(1) Sabre legacy mainframe system (www.sabreairlinesolutions.com/). This system is used for flight planning functions such as:

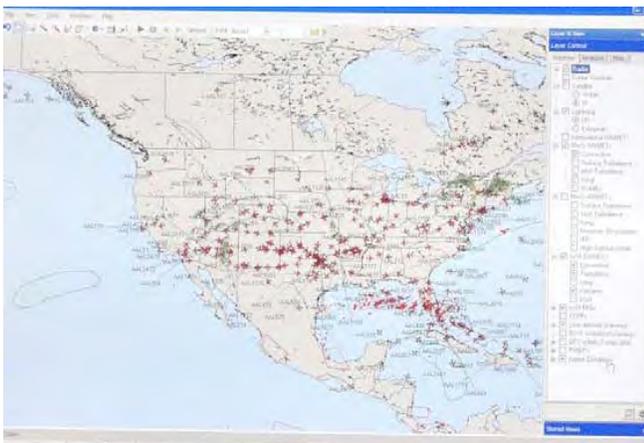
- Route optimization, taking into account fuel burn, time, and costs



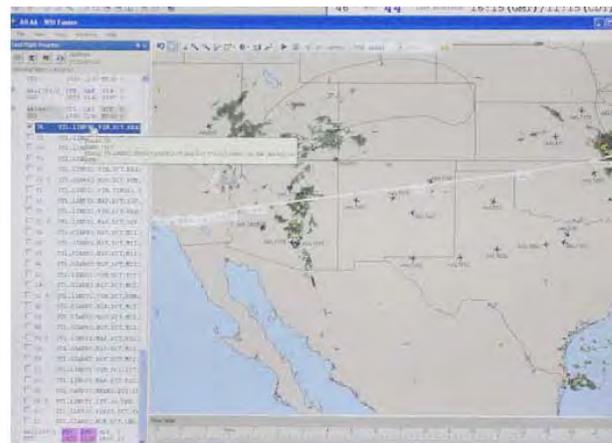
Figure 3. AOC, Airline 1

- Calculation of overflight costs
 - NOTAMs
 - Scheduling
- (2) WSI (www.wsi.com/aviation/solutions/). This airline contracts with WSI, which provides an onsite meteorologist and the WSI Fusion and Pilotbrief products. These products include the following information/functions:
- NEXRAD
 - Radar summary
 - Convective SIGMETs
 - AIRMETs
 - European Aeronautical Group (EAG) navigation data
 - Airline data such as the data block, tail number, flight number, origin, and destination
 - Identification of groups of flights by color. This is used by dispatchers to identify their flights at a glance.
 - Color coding on the flight-tracking display (with NEXRAD) to reflect altitude stratification

- Weather alerts so that the dispatcher knows when re-routing is necessary. Sample screens from WSI Fusion and WSI Pilotbrief are shown in Figures 4 and 5. The airline also uses the following tools and mechanisms to stay informed about weather:
 - » European Aeronautical Group (EAG) forecasts
 - » Aviation Digital Data Service (ADDS)
 - » NOAA Weather Center's Java tool
 - » Weather announcements
 - » Localized Aviation MOS (Model Output Statistics) Program (LAMP).
 - » Weather Briefings. The managers of the dispatch group, as well as the meteorologists, participate in a weather briefing conference call toward the beginning of each shift. During the briefing dispatchers receive information about arrival rates, runway configurations, weather, and any carrier issues.



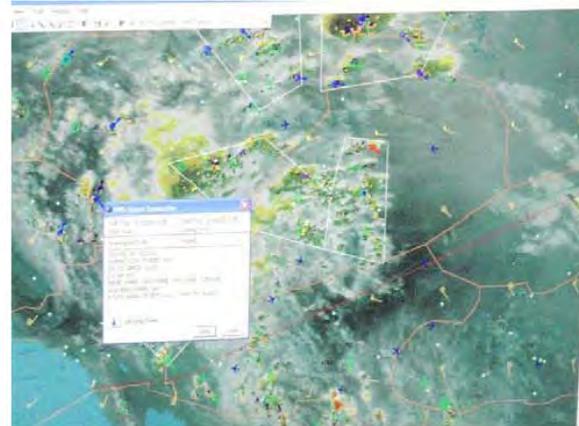
A



B

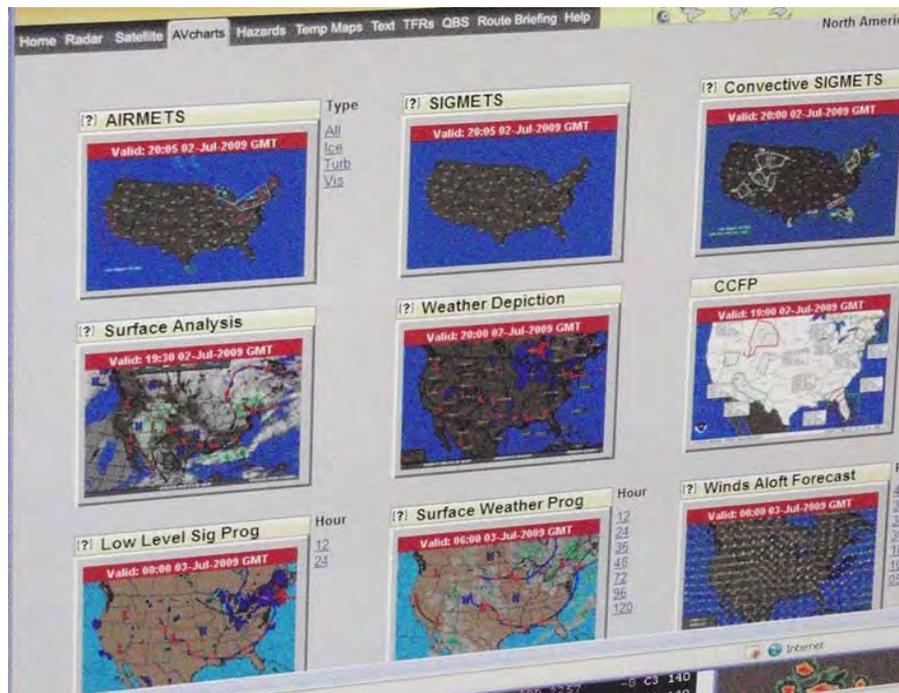


C



D

Figure 4. Sample screens from WSI Fusion. (A) All current flights for the airline, with flight numbers and the controls for displaying layers of information. (B) A radar display illustrating only that dispatcher's flights; one route is highlighted. (C) SIGMETs and the data blocks for the flights being followed. (D) Convective activity with a SIGMET in a dialog box



A



B

Figure 5. Sample screen shots from WSI Pilotbrief. (A) The variety of charts available for display; (B) A flight planning display with convective information

Airline 2

The second airline was a large carrier based in the Southeastern United States. A photograph of a portion of their AOC is provided in Figure 6.

The airline is the result of a recent merger of two already-sizeable airlines. As the operations merged, they were forced to use two different weather services. One uses Unisys, which provides raw data, which is then processed in-house and presented in a customized way. The other uses data from WSI, which is a value-added provider. The two contingents of the airline are working on integrating the systems to provide the best of both worlds. The WSI-focused process is described here. Examples of workstations are shown in Figures 7 and 8.



Figure 6. AOC, Airline 2

(1) WSI. This airline contracts with WSI to provide weather tools and information. WSI provides two onsite meteorologists to interpret the weather data and provide information to dispatchers in a meaningful format. For example, WSI first provides data via Weather Worx. Then the meteorologists customize the presentation and provide a 5- to 15-minute update. This time lag is required to clean up the data for consumption. Figure 8 shows a meteorologist's workstation.

WSI provides several other information products as well. These include:

- Turbulence chart: available for every city (shown in Figure 9). Updated twice a day, once for eastbound and once for westbound, this chart is used to estimate the cost to fly the route and is posted to the Intranet for pilots to examine and print.
- Text briefings: indicate the location of turbulence and storms.

(2) GFF. In addition, dispatchers utilize a program called Graphical Flight Following (GFF), which provides the following information:

- Flight information: altitude, origin, destination and route
- Convective updates: Provided every 3 hours for 36 hours, these integrate data from several sources and provide trend reports
- Satellite images: pictures of, and briefings for, "big weather," such as snowstorms and hurricanes
- Radar: a surface depiction chart (ADS), national and single-site radar



Figure 7. Dispatcher Workstation, Airline 2

- Collaborative Convective Forecast Product (CCFP). Convective forecasts for the following 3 to 5 days
- Surface chart (500 millibar): This is provided by NWS, and enables dispatch to see where weather is moving

Sample screens are shown in Figure 10.

(3) Co-developed program. With the assistance of WSI, this airline developed the Weather Information Display System (WIDS) to provide new forecasts, including position reports for turbulence. Sample screen shots are shown in Figures 11 and 12.



Figure 8. Meteorologist Workstation, Airline 2

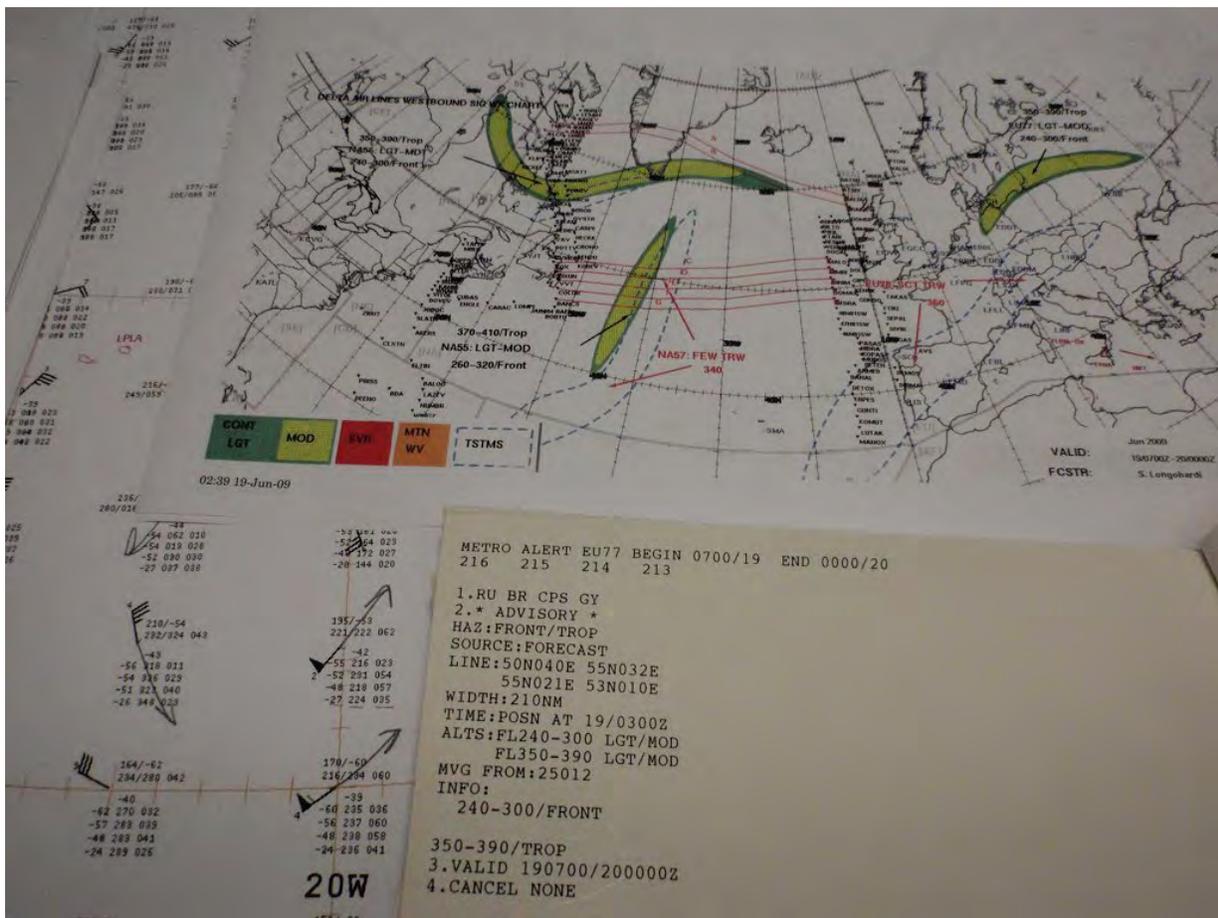
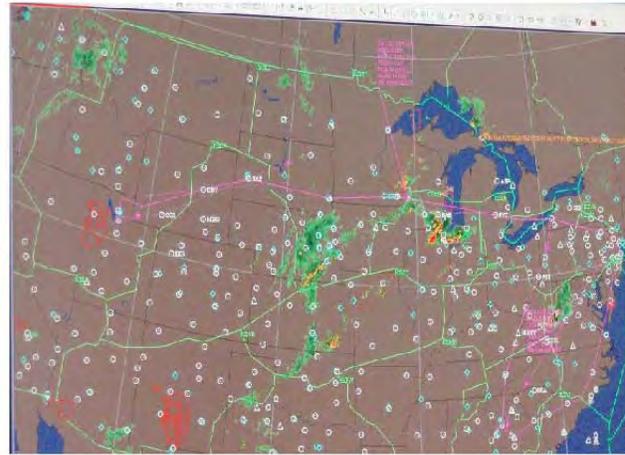


Figure 9. Turbulence Chart and Text, Airline 2



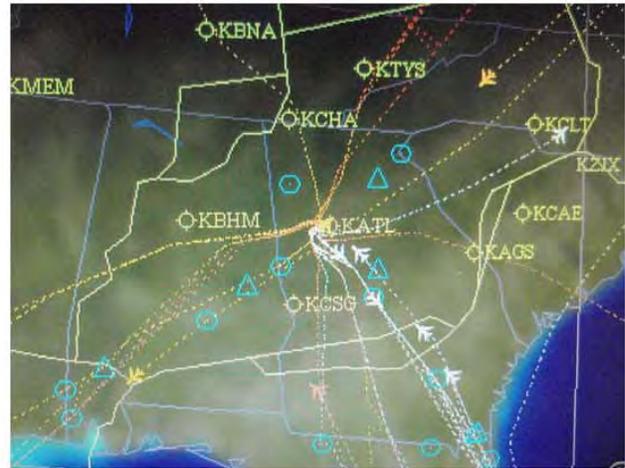
A



B



C



D

Figure 10. Sample GFF Screenshots from Airline 2. (A) GFF, Global View; (B) GFF, National View; (C) GFF, Atlanta Area/ (D) GFF, Atlanta Area Traffic

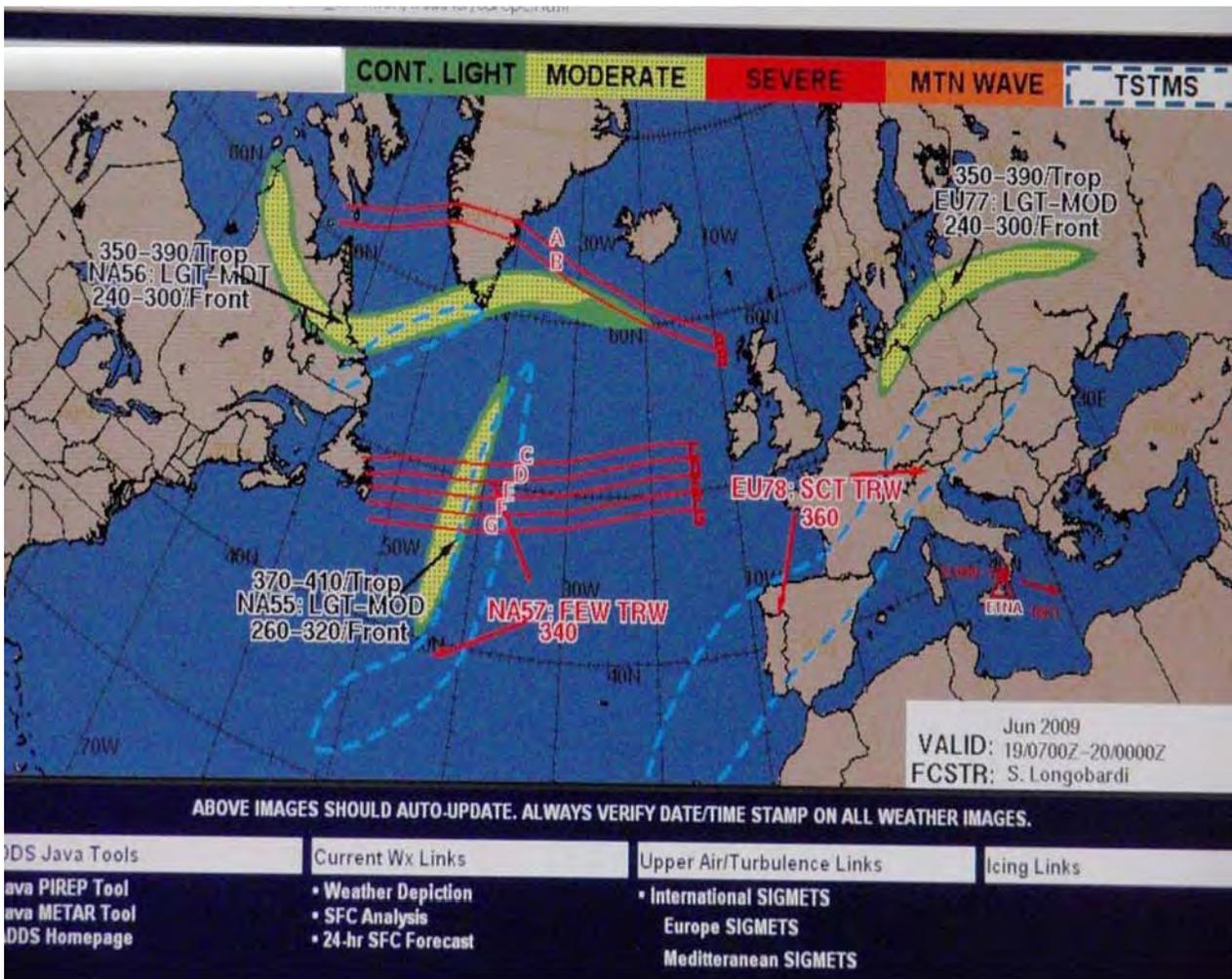


Figure 11. A convection display from the WIDS system, Airline 2

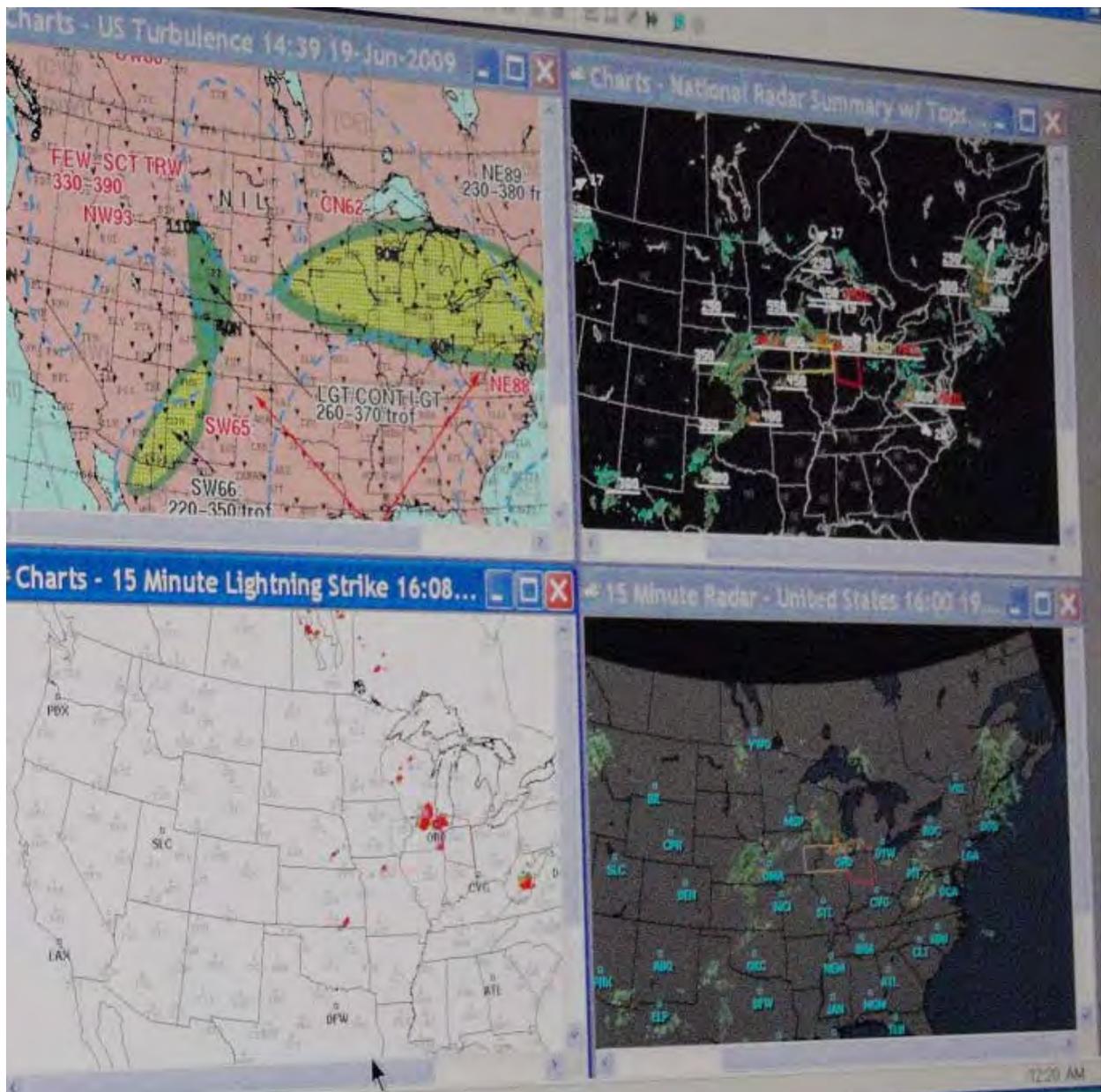


Figure 12. A screen shot of the WIDS system, illustrating its ability to show several types of information, each in its own window

(4) **LAMPs/CCFP.** Another program used is the LAMPs/CCFP hybrid. This combines the localized aviation MOS (Model Output Statistics) product with the Collaborative Convective Forecast Product. A photograph is shown in Figure 13.

(5) **Internet.** In addition, the Internet provides information that is used for supplementary purposes. Internet sources are not used as primary sources for two reasons: First, because of concerns for data quality, primary sources need to be Qualified Internet Communications Providers (QICP). Second, there are sometimes issues regarding computer memory cache. Specifically, concern has been expressed that dispatchers will mistake old weather data

for current data. On the other hand, many Internet tools are quite useful. For example, NOAA provides a Java tool that indicates clear air turbulence.

Airline 3

This regional airline is based in the Rocky Mountains and operates flights throughout the United States. A photograph of the AOC is shown in Figure 14.

This airline uses several weather products. Each is listed below with the information/products it provides.

(1) **WSI Pilotbrief.** This product provides:

- Radar (several products): NOWrad™ (National Operational Weather radar) Mosaic provides a radar

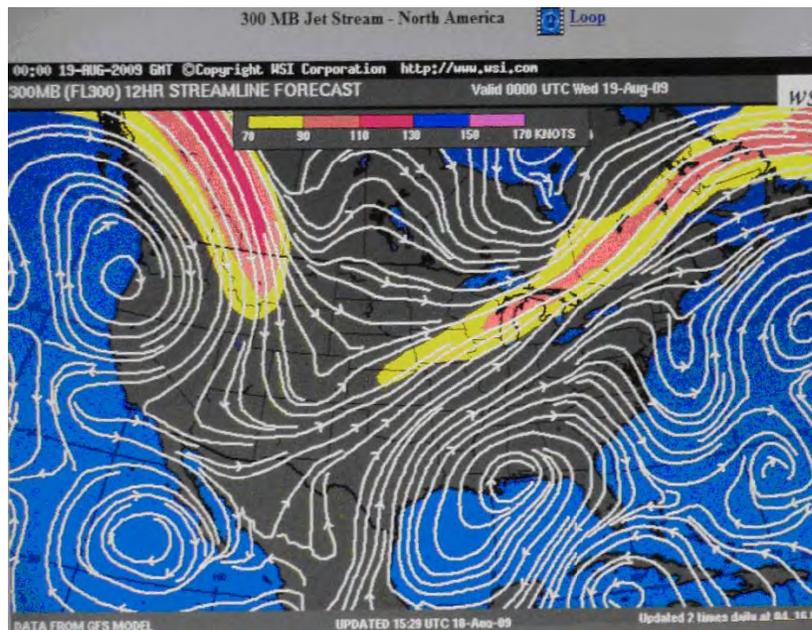


Figure 15. WSI Convection Information Display, Airline 3

picture with 2 km resolution, which is updated every 5 to 15 minutes, on both a regional and national basis. Data include echo tops, which indicate mesocyclones, tornadic activity, hail and severe weather watch boxes. Single-site radar provides specific radar images surrounding airports. A sample convection display is shown in Figure 15.

- Aviation weather (AV) charts
- SIGMETs
- AIRMETs
- Temporary flight restrictions (TFRs)
- Satellite imagery

(2) **Sabre Dispatch Manager** (www.sabreairline.com). The second program is the Sabre Dispatch Manager. Although Sabre does include some weather information, most weather is handled using WSI and Flight Explorer. Sabre, on the other hand, is used for flight planning functions such as:

- Schedule
- Crew
- Passenger
- Maintenance
- Payload
- Navigation information

(3) **Flight Explorer** (www.flightexplorer.com/). Provides flight tracking and graphical weather (see Figure 16), including:

- AIRMETs
- SIGMETs
- Frontal boundaries
- NEXRAD
- Clouds/ceiling information
- METARs
- On-site turbulence
- Runway crosswinds
- Graphical TAF bar

A particular benefit of Flight Explorer is that it enables these data to be overlaid on the same display, making it easier to see patterns in the data, diagnose problems, and reach conclusions.

(4) **CCFP** (Collaborative Convective Forecast Product, www.aviationweather.gov/products/ccfp/). Provided by NOAA. Depicts the coverage, growth rate, altitudes, and confidence level for convective currents. It shows these forecasts for two, four, and six hours. A sample display is shown in Figure 17.

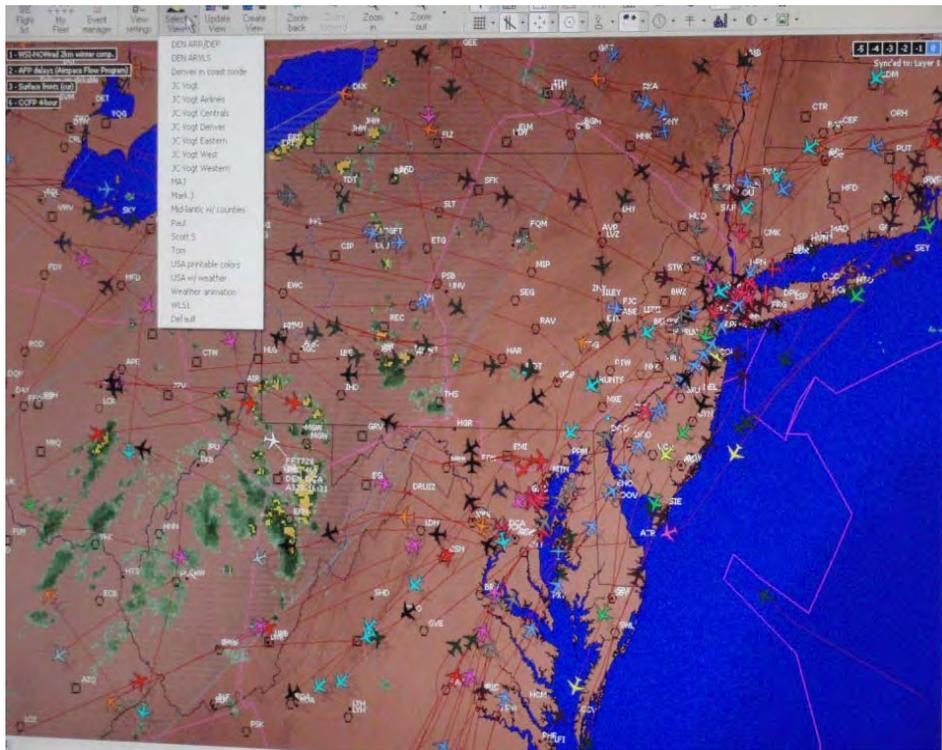


Figure 16. Flight Explorer Display, Airline 3

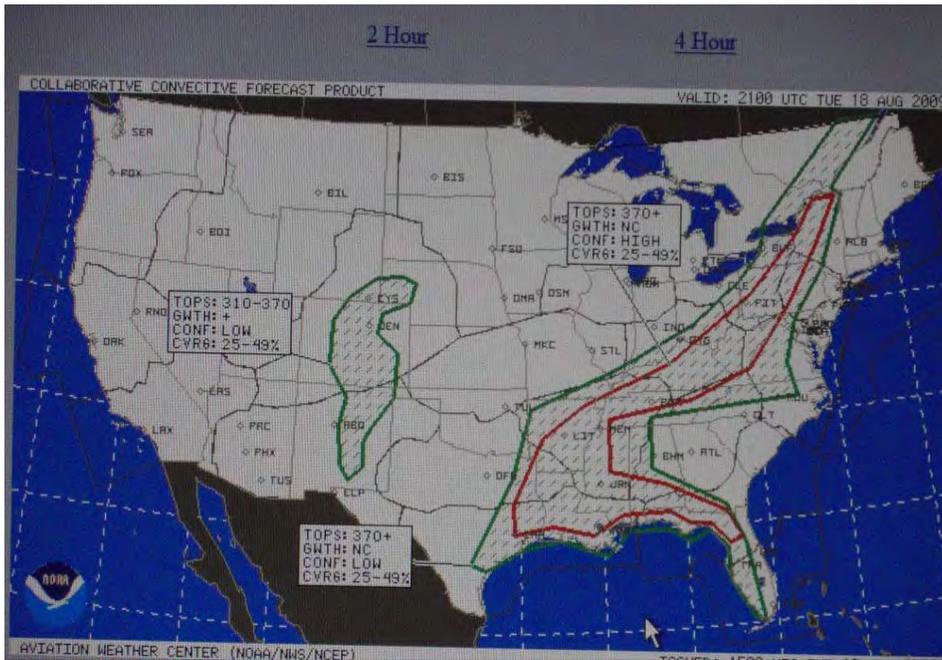


Figure 17. CCFP Display, Airline 3

Airline 4

This airline is regional and headquartered in the Southwest. It serves several parts of the Continental United States (CONUS), offers seasonal service to Alaska, and makes use of three software products for planning and flight following.

(1) **Sabre Dispatch Manager.** Used for dispatch planning and monitoring. It provides:

- TAFs
- METARs
- NOTAMs
- AIRMETs

Additionally, Sabre provides other data and functionality for calculating aircraft performance. For example, it determines a cruise altitude that will be the most fuel efficient and helps predict the need for extra fuel.

(2) **Flight Explorer.** The second software tool, Flight Explorer, offers information for flight tracking and graphical weather (see Figure 18). It makes available some of the same information as Sabre, but this information is presented graphically, which seems to aid decision making. In 2008, Sabre purchased the Flight Explorer Company, but the two systems have not been integrated yet. Flight Explorer includes:

- AIRMETs
- SIGMETs
- Frontal boundaries
- Radar
- Clouds/ceiling information

(3) **WSI.** Offers many of the information elements provided in Sabre and Flight Explorer, but this AOC uses it mainly for winds aloft information.

The dispatch manager at this airline found the current solution to be adequate, though she did mention a few things that could be improved. It seemed cumbersome to use Sabre for Dispatch Management and Flight Explorer for examining weather and visually tracking flights. In general, she would like to see many of the functions (PIREPs, for example) move to a more graphical format, as this seemed to make it easier to reach conclusions.

DISCUSSION

The interviews and observations raised some important questions regarding the needs of AOCs currently and as envisioned for the NextGen environment.

What are the dispatcher's goals?

In discussing work activities, it is often important to begin with a description of the worker's goals and responsibilities. In broad terms, the dispatcher has five goals:

- Ensure safety of flight
- Minimize fuel consumption
- Maximize payload
- Keep flight on schedule
- Keep the pilot updated

Products that assist the dispatcher in the achievement of these goals are most likely to increase the margin of safety and hopefully reduce dispatcher workload. Ensuring safety typically entails choosing routes that avoid "big weather," choosing appropriate departure and arrival

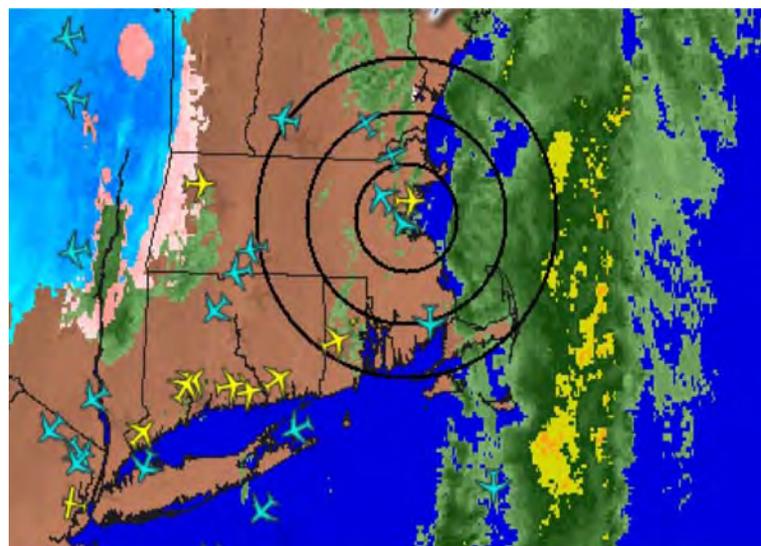


Figure 18. Flight Explorer Display, Airline 4

Table 4. Product Use by 4 Airlines

Airline #	Sabre				Flight Explorer				WSI				NWS				NOAA			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Dispatching	X		X	X																
METARs				X			X			X										
TAFs				X			X													
NOTAMs				X																
AIRMETs				X			X	X	X	X	X									
SIGMETs				X			X	X	X	X	X									
TFRs											X									
AV Charts											X									
Radar							X	X	X	X										
Satellite imagery								X	X	X										
Clouds/ceiling							X	X	X	X										
Frontal boundaries							X	X												
Surface chart										X				X						
Turbulence chart										X										
PIREPs								X		X										
Convective updates										X										
Clear air turbulence																		X		
On-site turbulence								X									X	X		
LAMPs/CCFP																		X	X	
Runway crosswinds								X												

Note: The table only shows the products used from each source and not all products available.

alternatives, and avoiding turbulence. It is the last of these that is the most difficult. Turbulence can be very localized and difficult to detect, so the dispatcher must sometimes rely on PIREPs. Unfortunately, if PIREPs are present it means that some flight has probably flown through that turbulence.

Fuel management and payload optimization are achieved through smart planning. Choosing routes with the best weather is one method for doing this. Typically, tools like WSI and Flight Explorer assist the dispatcher in making these decisions.

Keeping the pilot updated is crucial for dealing with turbulence and ensuring customer safety and comfort. Communicating turbulent conditions to the pilot in a timely manner enables the pilot to change altitude or to warn passengers of impending turbulence.

Each dispatcher is responsible for six to 12 international flights or 20 to 60 domestic flights. Typically, the dispatchers try to plan the flight so well that the pilot never needs to talk to them (even though the dispatcher is required by the FAR to provide updates to the pilot). In

our interviews, one dispatcher commented that, “PIREPs represent a failure to me.” The big challenge seems to be identifying turbulence and convective activity. Other types of weather phenomena are more obvious and can be planned for relatively quickly.

What products are airlines using?

Table 4 illustrates the products that airlines are using now. It demonstrates that all of the airlines use more than one product. Three different activities are supported by three different categories of support programs: Sabre for dispatch management, Flight Explorer for flight following, and WSI for weather monitoring and forecasting. In actuality, many of the programs have all three capabilities, but each seems to have a major strength in one. This is what led Sabre to Purchase Flight Explorer in 2008.

The following observations should be emphasized:

- Airlines 1 and 2 operate worldwide, whereas airlines 3 and 4 are national and regional, respectively.
- Airline 1 uses a legacy mainframe dispatch system originally developed by Sabre.

- Overall, WSI was the most frequently used product. In fact, it was used by all of the airlines interviewed.
- The major carriers (Airlines 1 and 2) were more likely to use WSI as an information provider, and to customize the presentation of that information for their own use. For example, Airline 1 created a product called the Aircraft Operations Dashboard, and Airline 2 created an internal product called Graphical Flight Following (GFF). Given the number of flights they need to plan and the cost of fuel, they decided that flight management was crucial to operational efficiency. In fact, both of these airlines contracted with WSI for on-site support.

Are the airlines interested in switching products?

None of the airlines expressed an interest in switching products but were more interested in refining their products through customization and intelligent combination of information. This has been the approach of the major airlines. Dispatchers often shared hints on screen configurations that were “easier to look at.” Upon further discussion, we learned that “easier to look at” meant that it was more effective for decision making. Of course, the AOCs are always interested in improvements in weather prediction and improved information displays. We can expect them to use the new products envisioned in moving toward NextGen.

The interviews and observations suggest that dispatchers have a substantial amount of information and numerous planning tools at their disposal. Dispatch-management programs enable them to make decisions about fuel, passenger load, and so on. Flight-following tools like Flight Explorer enable them to track flights and observe weather patterns at the same time, providing overlays of satellite images and so on. Weather forecasting programs like WSI serve as end-user programs in their own right but also enable the database to be used for custom weather information management programs. This was the strategy being used by the major carriers we interviewed.

What are the differences between large and small carriers?

There were a few differences between the major carriers and the smaller ones, but the differences had little to do with actual planning and flight-following activities. Instead, the major carriers were more involved in the customization and constant refinement of their own weather and dispatching systems. This may have been because they had larger technology budgets or may have been because weather planning offers them a larger return on investment. With longer routes, there is more flexibility and more to be gained by increasing the efficiency

of the flight (minimizing distance and fuel), and there is greater opportunity to make early adjustments to avoid adverse weather.

How does the weather information provided in each product compare to the prioritized list?

The weather information provided by WSI and Flight Explorer match the prioritized list of weather factors quite well. The priority ratings show that items such as cloud/ceiling, precipitation, thunderstorms, visibility, and wind are crucial to dispatchers. This is precisely the information provided by the WSI and Flight Explorer tools, via AIRMETs, SIGMETs, radar, convective updates, satellite imagery, and the like.

Sabre Flight Manager matches these factors less well, but its strength is in flight planning, fuel management, crew management, and so on. From our interviews, it seems that it is almost always used in combination with Flight Explorer or a WSI product.

What information is needed, but is not available?

A sizeable industry has grown around weather description and forecasting. As a result, dispatchers have much of the information they need. In fact, during interviews it was often difficult to entice them to discuss things they did not have at their disposal. There was one exception, however, the ability to detect turbulence without having to actually fly through it was at the top of the dispatchers’ list of needs. As the one dispatcher mentioned, “PIREPs represent a failure on my part.” Anything that can detect turbulence and bring it to the attention of dispatchers would be welcomed. One dispatcher at a regional airline indicated a need for graphical PIREPs. This functionality exists already, but she did not have access to it.

Another issue arises with the rapid development of graphical weather products that are available from the National Weather Service over the Internet. Some of these products present information in formats that are superior to what is available in earlier products. However, the requirement that primary weather sources come from Qualified Internet Communications Providers (QICP) limits the use of any information without this designation. There are also frequent changes made to the NWS products and services. Some standardization and a method to reach the QICP designation rapidly as new products are developed could improve the quality of the information available to dispatchers.

Where is information available, not commensurate with its importance?

As can be seen in the photographs of the dispatchers’ workstations, they usually have at least three computer monitors on their desks, and some monitors have three

or four windows open at any one time. This enables them to keep the combination of information elements they need visible when they need it, arranged to their liking. In that sense, the customization by the dispatcher mitigates the product design shortcomings. This customization, though not ideal, ensures that the information availability is commensurate with its importance.

The ability to have multiple windows open at one time is critical. It is also helpful to have multiple monitors. This enables dispatchers to compare and contrast displays and look for patterns from multiple sources, as well as converging or diverging evidence.

What information is important to show together?

The weather factors diagram shown in the Method section illustrates the pieces of information that should be shown together. Five main clusters: precipitation, clouds, visibility, temperature, and wind should be shown together because of their similarity. There are also factors that mediate those clusters. For example, front location and type is associated with both precipitation and wind clusters. This suggests that Front location/type, wind, and precipitation should be presented at the same time, mainly because of their co-occurrence.

What is needed in the NextGen environment that does not yet exist?

Part of the dispatcher's time is spent interacting with ATC. In fact, the ability to improve communication with ATC is often seen as an opportunity for improved efficiency. Often the dispatchers have knowledge about the characteristics of the airplane models that are not readily available to ATC and can assist ATC in choosing runways and so on.

Another strategy that could be explored involves decision support. For example, at times it may be helpful to make suggestions (or select appropriate defaults) for the dispatcher. One instance of this is when selecting arrival or departure alternates, these are sorted according to proximity to the aircraft. Instead, it may make sense to sort them according to a combination of factors including weather, proximity, runway appropriateness, and so on. A similar approach could be taken to flight diversion.

One idea worth exploring is to have systems that are able to represent flights as 4-dimensional trajectories, indicating where a flight should be in space at any given time. Such 4-D models could allow the development of alerting systems for dispatchers, which would indicate flights that are likely to encounter some weather problems at projected times in the future. Flights at risk could deliver alerts, with priorities tied to the time-to-trouble as well as the severity of the weather problem. Such a system would be especially useful for managing dispatchers' workloads in times of deteriorating weather conditions.

What information do pilots and dispatchers need?

This question is partially addressed by reference to the priority ratings in Table 1, which shows the importance of weather factors for both dispatchers and pilots in planning and flight-following. Those data showed that most of the weather factors examined were high-priority items at some point in planning or during the flight. One factor, *Vertical Temperature Gradient*, was not judged to be important at any point. As for differences between dispatchers and pilots, dispatchers generally rated several factors (including *Cloud Coverage*, *Rain*, *Snow*, and several *Wind* factors) as higher priority than did pilots during planning. Pilots gave *Barometric Pressure* and *Density Altitude* higher priorities than did dispatchers during planning. During flight, most of the factors were of high priority at some point, but pilots again gave *Barometric Pressure* and *Density Altitude* higher priority than did dispatchers. In addition, pilots gave *Temperature* higher priority during flight than did dispatchers.

In an earlier study (Schvaneveldt et al., in press), we found that information priorities varied considerably over the course of a flight for GA pilots. That study included three phases of the flight (departure, en route, and arrival) in addition to planning. For dispatchers, it made more sense to consider only two phases, planning and flight following, because this is how they organize their activities. Consequently, the data from pilots were collapsed across in-flight phases for comparison by taking the maximum priority for each factor across the flight phases. This collapsing obscures the fact that priorities do change for pilots during the flight, and as we argued in the earlier paper, the workload for pilots could be reduced by having the right information available at the right time. Ideally, information tied to the 4-D profile of the flight would be appropriate for pilots who need to know about factors relevant to their particular flight. The situation for dispatchers is quite different because they are simultaneously involved with several flights with various 4-D profiles. Dispatchers need a bigger picture of the weather to accomplish their tasks. Of course, they have the luxury of having multiple large displays that can be customized to their needs. The limits of the cockpit place more constraints on displays for pilots.

It is important to recall that the small differences that we observed between the GA pilots' ratings and the Part 121 pilots' ratings were apparently attributable to operational environment differences. Perhaps the two major differences are that airline pilots: (1) are expected to fly as near to the flight schedule as possible, and (2) have dispatchers looking out for their flights from the planning to the arrival and providing integrated or summarized weather data. Dispatchers can identify many potential problems and can find and negotiate solutions to the

problems with ATC. The GA pilots, in their environment, are largely responsible for all data gathering, integration, interpretation, and clearance negotiation. Thus some of the weather factors were likely of less importance to the Part 121 pilots because they did not have to deal with them routinely because of assistance from dispatch. Thus, even among pilots, there are presently slightly different levels of need for specific weather data.

What are the major implications for changes envisioned under NextGen?

The plans for NextGen being developed by the FAA can be examined at the website, <http://www.faa.gov/nextgen/>. The primary goal of NextGen is to improve the efficiency of the national airspace system (NAS) to handle expected future increases in traffic and to reduce delays due to traffic conflicts and weather. We do not address traffic issues in this report, but the NextGen goal to reduce weather impact is directly relevant. This NextGen goal is addressed by several activities including aviation weather research, weather information improvements, weather technology in the cockpit, weather information integration, and NextGen Network-Enabled Weather (NNEW).

NNEW will provide weather support services. It is intended to enable widespread distribution of weather products to enhance collaborative and dynamic decision making. Network access to weather information will come from a myriad of sources (such as weather processor and radar processor replacement, DoD, NOAA) and be available to all users. In addition, weather information will be integrated into NextGen decision-support systems. Among the tools to be included is the 4-D Weather Data Cube.

Because NextGen envisions less ATC control and contact with flights after departure and until arrival, we can consider how this reduced contact might affect Part 121 operations. Currently, AOCs serve to gather, analyze, and communicate weather information for the flights under their control. There are commercial/competitive reasons for airlines to develop the best weather information they can, reasons that will not change with changes in the NAS. Thus, transition to NextGen should have little effect on these operations. Airline pilots can be expected to continue getting the majority of weather information from dispatchers. Of course, it is critically important that pilots continue to receive timely information about conditions affecting departure and arrival airports such as barometric pressure, density altitude, temperature, and runway conditions, which appear from the priority ratings to be of less concern to dispatchers. However, dispatch can provide pilots with necessary updates on weather en route.

Diversions from planned routes are potentially a greater problem. It is relatively easy to envision ATC minimizing conflicts and delays by scheduling flights, but major issues arise when diversions are required. Diversions are usually due to factors like adverse weather that may affect rather broad geographical areas. Currently, Part 121 dispatchers negotiate with ATC to determine acceptable alternate routes, and the resolution is then passed on to the pilot, usually by the dispatcher. Any changes in the interaction of dispatchers and ATC must have effective methods for detecting, communicating, and negotiating diversions.

CONCLUSIONS

AOCs follow well-developed procedures for collecting, analyzing, and communicating weather data. While there are small differences between the airlines, they all consult several information sources to develop a picture of weather relevant to their flights. The larger operations develop products of their own, often based on data delivered from a commercial source of weather information. In all cases, pilots receive weather information regarding their flights compiled by dispatchers, and further information is communicated to pilots during the flight. With the depth of the preparation in flight planning and the responsiveness of dispatchers to changes in weather conditions, pilots are operating under the continual guidance of dispatchers. Given this system, it appears that changing the NAS as envisioned under the NextGen concept will have little impact on Part 121 operations. A possible exception to this conclusion might arise in connection with the need for diversions or other changes in routes. It is critical that NextGen either maintains the communication that now exists in such circumstances or that the changes made do not jeopardize the ability of the dispatcher-pilot team to deal effectively with diversions.

Although we do not foresee that NextGen will require major changes in the operation of AOCs, there are several ways to improve the delivery of weather information, the operation of the dispatchers work environment, and decision support tools for dispatchers. Specific suggestions for such improvements include:

- Standardize the method used to achieve QICP designation for new Internet-based weather products
- Display weather data together in the 5 identified main clusters
- Improve AOC-ATC communications
- Employ decision-support tools
- Use 4-D flight models to match weather forecast time points
- Prioritize displayed weather information according to relative importance by phase of flight
- 3 phases for pilots
- 2 phases for dispatchers

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APPENDIX A
From Heuwinkel (1993)

Figure 1.
Summary of Users Aviation Weather Information Needs

Weather Information		User Group		
		PILOTS	DISPATCHERS	AIRPORT MANAGERS/ OPERATORS
I. SIGNIFICANT WEATHER				
1	Convective Activity/Initiation	S	S	S
2	Lightning	S	S	
3	Microburst/Gust Front	S	S	
4	Low Level Wind Shear	S	S	
5	Icing and Freezing Level	S	S	S
6	Widespread Low Visibility	S	S	
7	Clear Air Turbulence	S	S	
8	Other Turbulence	S	S	
9	Wake Vortex Detection/Dissipation	S		
10	Volcanic Ash	S	S	
II. ROUTINE WEATHER				
1	Cloud Bases, Tops, Coverage	S	S	S
2	Ceiling	S	S	S
3	Surface Visibility	S	S	S
4	Runway Visual Range	S	S	
5	Inflight Visibility	S	S	
6	Wx/Obstruct to Vision/Surf Cond	S	S	S
7	Surface Temperature	S	S	S
8	Surface Dewpoint	S	S	C
9	Surface Wind/Wind Shift Prediction	S	S	S
10	Altimeter Setting	S	S	
11	Density Altitude	S	S	
12	Pressure Patterns/Fronts	S	S	
13	Winds and Temperatures Aloft	S	S	
14	Tropopause Height & Temperature	S	S	

LEGEND

- High Priority
- Medium Priority
- Low Priority
- S Safety Primary Benefit
- C Capacity Primary Benefit
- E Efficiency Primary Benefit
- Regulatory

Figure A1. Heuwinkel's Figure 1, Weather information needs for 3 user groups

Summary of Part 121 Pilots Aviation Weather Information Needs

Phase of Flight	Pilot Activity	Weather Information																							
		1 Convective Activity/Initiation	2 Lightning	3 Microburst/Gust Front	4 Low Level Wind Shear	5 Icing and Freezing Level	6 Widespread Low Visibility	7 Clear Air Turbulence	8 Other Turbulence	9 Wake Vortex Detection/Dissipation	10 Volcanic Ash	1 Cloud Bases, Tops, Coverage	2 Ceiling	3 Surface Visibility	4 Runway Visual Range	5 Inflight Visibility	6 Wx/Obstruct to Vision/Surf Cond	7 Surface Temperature	8 Surface Dewpoint	9 Surface Wind/Wind Shift Prediction	10 Altimeter Setting	11 Density Altitude	12 Pressure Patterns/Fronts	13 Winds and Temperatures Aloft	14 Tropopause Height & Temperature
PREFLIGHT	1. Review preflight weather information	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	2. Request additional weather information for preflight planning	E	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
TERMINAL DEPARTURE	1. Taxi to the departure runway	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	2. Configure the aircraft for takeoff	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	3. Takeoff from the departure runway	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	4. Climb the aircraft to the cruise altitude	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
EN ROUTE	1. Monitor en route weather conditions	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	2. Monitor airport conditions	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
APPROACH and LANDING	1. Descend and merge with airport traffic	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	2. Align the aircraft with the landing area	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	3. Land the aircraft on the arrival runway	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	4. Exit the runway and taxi to the parking ramp	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
	5. Park the aircraft	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

LEGEND

- High Priority
- Medium Priority
- Low Priority
- S Safety Primary Benefit
- C Capacity Primary Benefit
- E Efficiency Primary Benefit
- S Regulatory

Figure A4. Heuwinkel's summary of Part 121 pilots' weather information needs

Summary of Airport Manager/Operator Aviation Weather Information Needs

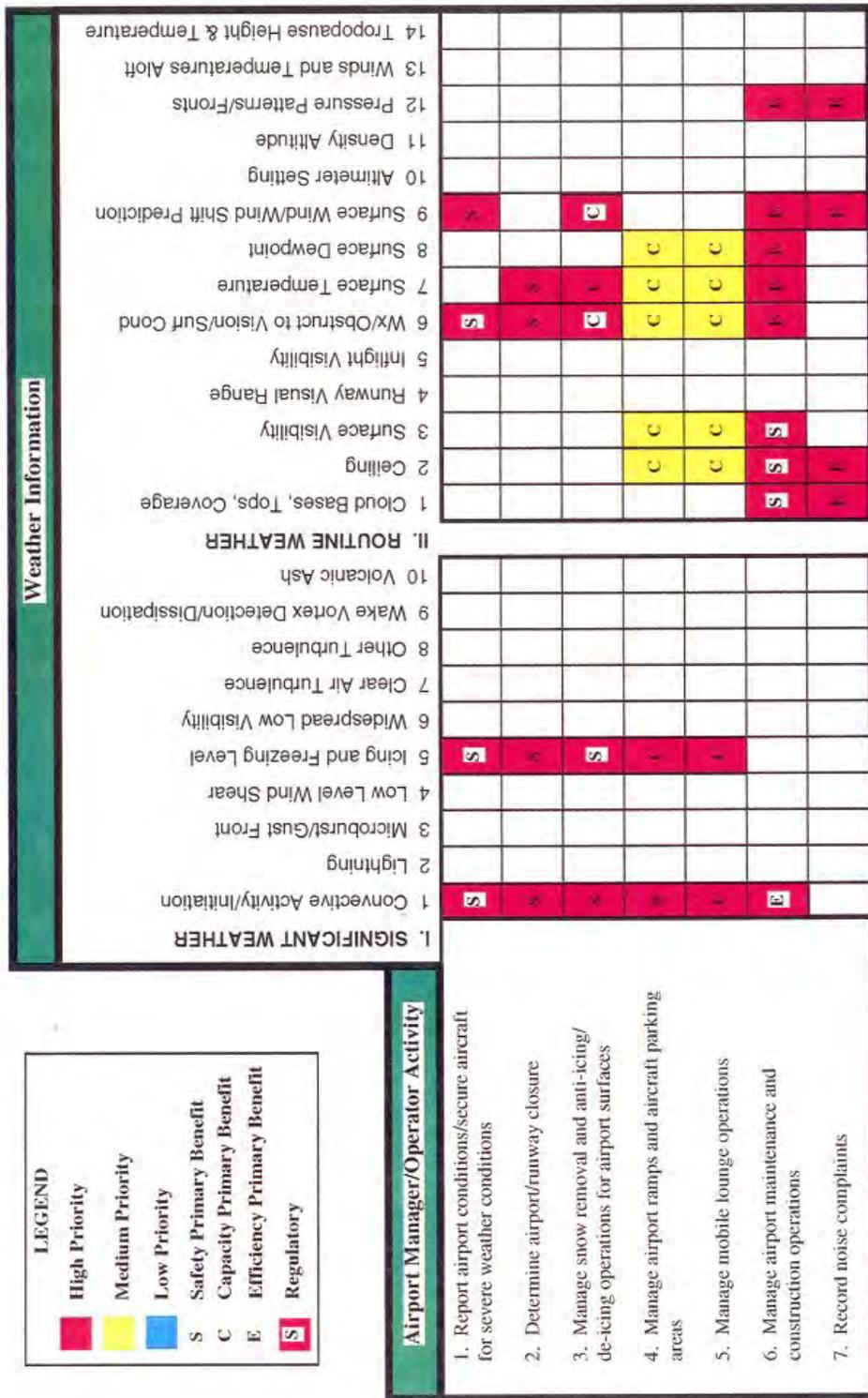


Figure A6. Heuwinkel's summary of airport managers' weather information needs