P3.9 IMPACTS OF THE DECEMBER 22, 2004 WINTER STORM ON FEDEX'S MEMPHIS OPERATION

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1. INTRODUCTION

It is a sight to behold – 150 jet aircraft descending on the "SuperHub", a million plus packages unloaded, sorted, and reloaded on the aircraft, and the same birds departing – all in the middle of the night over a six hour period. This is the time-sensitive operation that FedEx Express runs five nights a week, year-round, at Memphis International Airport (MEM), Memphis, TN. And as with all airline operations, weather plays a key role in just how well the diligently-planned schedule unfolds. Co-located with the Global Operations Control (GOC) facility in Memphis, where flight dispatchers and operations managers constantly monitor and tweak the system, FedEx meteorologists provide forecasts for every city that trunk aircraft fly into and brief GOC management, dispatchers, and pilots on potential weather issues. The busiest time of year for FedEx cargo operations is the time from Thanksgiving to Christmas, commonly called "peak," with the most crucial period being the last few days before Christmas, when many last minute shoppers "FedEx" their Christmas gifts to friends and loved ones. Volume spikes that week with as much as a 30% increase over normal flow system-wide; any minor disruptions can easily escalate into major issues.

On December 22, 2004, a cold front was positioned east of Memphis through middle Tennessee and eastern Mississippi, low pressure was located along the front over northern Louisiana and central Mississippi, and an upper-level trough was traversing the region. This combination was producing precipitation over the Mid-South that began as rain, transitioned to freezing rain, continued for several more hours as light to moderate sleet, and ended as light snow. In the end, the region was blanketed with 2 inches of frozen precipitation, making basic exercises such as walking and driving treacherous. Needless to say, airline operations came to a near standstill and since cold air advection brought bitter cold temperatures for several days, a lack of melting resulted in extended impacts even after the precipitation ceased. FedEx aircraft that arrived in MEM before or during the freezing precipitation event "turned into popsicles" as they sat on the ground and endured freezing temperatures through Christmas Day. In the end, hundreds of flights filled with boxes and envelopes containing Christmas cheer were cancelled and many shipments were delayed. Following the usual post-mortem FedEx undertakes after significant weather events, adjustments have been made to the winter operations procedures. In this paper, we will provide a broad overview of the Meteorology Department's role in FedEx's domestic air operation, examine the environment in the time period around the event in question, and finally look at how the storm affected both air and hub/ground operations in Memphis during Peak Week 2005.

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2. OVERVIEW OF WEATHER SERVICES DEPARTMENT

The Meteorology Department (formally called Weather Services) is a part of FedEx Express Air Operations Division (AOD) and has as a portion of its mission to "provide the most accurate weather forecasts and briefings for North American and Caribbean operations…to ensure FedEx remains the safest, most reliable and cost-efficient air transportation system in the world." The department is approved by the Federal Aviation Administration (FAA) as the primary source of forecasts for all domestic trunk flights and operates around-the-clock with a staff of 15 meteorologists. Forecasters issue terminal forecasts for nearly 150 domestic, and a few international, locations twice a day with valid times of 16-25 hours. A couple of sample forecasts are shown in Figure 1. Detailed ceiling and visibility forecasts are issued only when conditions drop below Visual Flight Rules (VFR) conditions; otherwise, the forecast indicates "ABV 2000/3," meaning the ceiling will remain above 2000 feet and the visibility above 3 miles.

Other responsibilities of the meteorologists include issuing SNOCON alerts for the SuperHub at MEM and Regional Hubs at Indianapolis, IN (IND), and Newark, NJ (EWR) when frozen precipitation is expected within 48 hours; forecasting temperature, wind, and altimeter settings for hubs and select western U.S. cities during the summer months; issuing daily weather outlooks and participating in shift change briefings for FedEx flight controllers; and providing other guidance and briefings, as requested, for flight controllers, pilots, and other entities within the Corporation.

Because a large portion of FedEx's domestic air operation runs through the Memphis SuperHub, the winter storm of December 22, 2004 had a significant impact on the entire FedEx network. In the days and hours leading up to this event, the Meteorology Department was extraordinarily busy gathering

information, forecasting, and relaying the expected conditions to senior management in GOC – the "nerve center" of the airline. During the event, management, along with flight controllers that were dispatching and monitoring individual flights, was kept abreast of changing conditions by the meteorologists on duty.

3. ENVIRONMENTAL CONDITIONS

As with most significant weather events, several factors came together to produce the winter storm that coated the Mid-South with ice and snow. The Meteorology Department was monitoring these conditions well in advance of the event and issued a winter weather alert for MEM 48 hours in advance of the onset of frozen precipitation. On December 21st, a surface low was located across northern Texas and an upper level trough was digging into the Rockies, allowing for warm air and moisture advection over the Tennessee and Mississippi Valleys. High temperatures in Memphis on the 21st were in the mid 60s, as moisture fed into the region. By late Tuesday evening, light rain began to fall as a cold front approached the region from the northwest. The rain further intensified early Wednesday morning as the front moved over Memphis. At 0600 local (12Z), the surface plot (shown in Figure 1) shows low pressure over west-central Louisiana with a stationary front extending northeast to just south of Memphis and into central Kentucky. After frontal passage (0300 local Wednesday), the temperature at MEM dropped into the mid 30s with Arctic air positioned over the central plains and advecting southward into the Tennessee Valley (data from MEM surface observations is shown in Table 1). The 12Z ETA 300mb analysis (Figure 2) shows an 80-100 knot Arctic jet rounding the base of the trough from west to east Texas. By noon on December 22nd, the low had moved to eastern Louisiana. The wet bulb temperature dropped to 31 degrees F at 1209 and light rain became freezing rain (see radar image in Figure 3), while the actual temperature dropped to the freezing point at 1253 (see surface observations in Table 1).

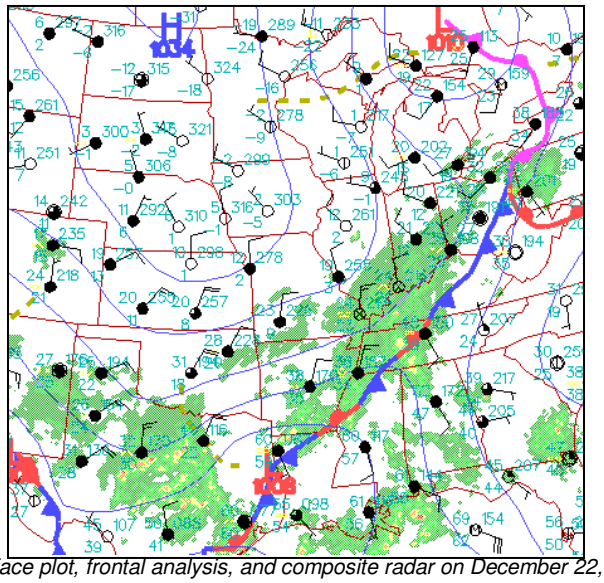

Figure 1. Surface plot, frontal analysis, and composite radar on December 22, 2004 at 12Z.

Time (LST)	Sky Condition	Visibility	Weather	Wind	Temperature	Wet Bulb	Dewpoint
0853	BKN006 OVC013	10SM	-RA	020/16	36	34	32
0953	OVC008	10SM	-RA	020/14	36	34	32
1053	BKN008 OVC013	7SM	-RA	020/15	35	33	31
1153	OVC008	7SM	-RA	030/15G25	33	31	29
1209	BKN007 OVC011	6SM	-FZRA BR	020/16G21	-	-	-
1219	BKN007 OVC011	4SM	FZRA BR	020/17	-	-	-
1232	BKN007 OVC011	6SM	-FZRA BR	030/16G26	-	-	-
1253	BKN007 OVC011	10SM	-FZRA	020/19G24	32	31	28
1307	OVC011	10SM		030/17G22	-	-	-
1325	OVC011	10SM	-FZRA	030/15	-	-	-
1343	OVC011	2SM	-FZRAPL BR	030/15	-	-	-
1353	OVC011	2SM	FZRAPL BR	020/13G18	31	30	27
1403	OVC011	2SM	PL BR	030/18G23	-	-	-
1419	BKN008 BKN013 OVC018	2SM	PL BR	040/21G26	-	-	-
1453	FEW006 BKN010 OVC018	2SM	PL BR	020/11	31	30	28
1505	FEW006 BKN011 OVC020	3/4SM	PL BR	020/12	-	-	-
1514	BKN006 BKN014 OVC021	3/4SM	PL BR	020/15	-	-	-
1553	BKN006 BKN012 OVC018	3/4SM	PL BR	010/15G19	29	28	26
1653	BKN006 BKN014 OVC026	3/4SM	PL BR	360/17G22	25	24	21
1727	FEW012 BKN019 OVC030	1SM	PL BR	010/23G28	-	-	-
1753	SCT014 OVC026	5SM	PL BR	020/18G27	24	22	19
1824	SCT014 OVC026	1SM	PL BR	010/14G24	-	-	-
1853	SCT014 SCT021 OVC028	1SM	PL BR	350/10	23	22	19
1939	FEW007 BKN025 OVC030	1SM	PLSN BR	010/18G21	-	-	-
1953	SCT014 BKN025 OVC030	1SM	SN BR	010/15G21	23	21	18

Table 1. Select surface observation data from MEM for a portion of December 22, 2004.

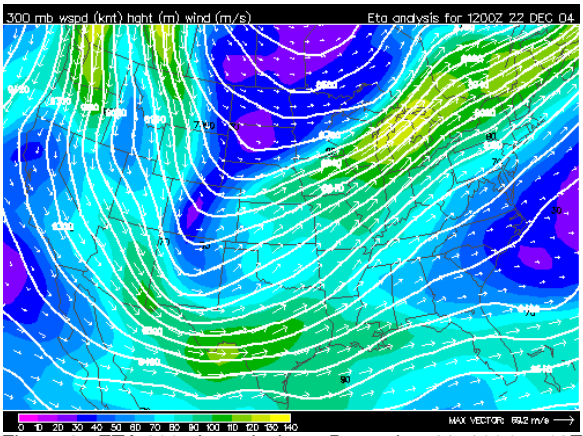

Figure 2. ETA 300mb analysis on December 22, 2004 at 12Z.

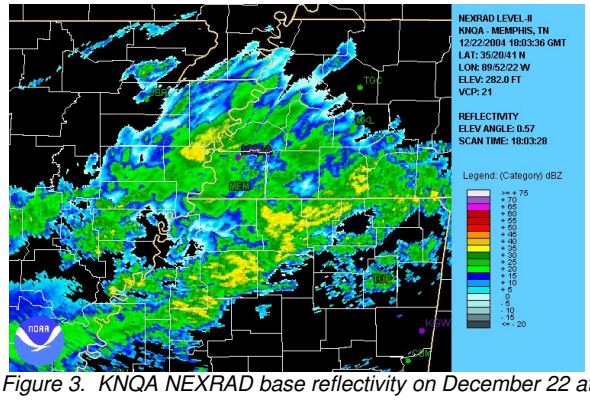

Figure 3. KNQA NEXRAD base reflectivity on December 22 at 1803Z (1203 LST). The radar position is indicated by the purple dot and label (KNQA). Memphis International Airport (also labeled) is located 20 nm south-southwest of KNQA.

As the front left quadrant of the upper level jet nosed into central Mississippi (Figure 4) and low pressure moved along the stationary front towards west-central Mississippi (Figure 5), the ingredients came together to allow for moderate freezing rain and ice pellets by 1353. Figure 6 shows the corresponding NEXRAD image depicting 35+ dBz reflectivity over the airport. Bright banding, which shows the location of the freezing layer aloft, is depicted in the NEXRAD surface reflectivity image from KNQA (Millington, TN) at 2058Z (or 1458 LST) [Figure 7] with moderate ice pellets lingering until 1900. Figure 8 depicts the 18Z sounding from Little Rock, Arkansas, which shows an inversion between 925mb and 750mb that created a warm layer

aloft and allowed for the freezing rain and ice pellets at the surface. Had the temperature inversion been located further south, freezing air at that level would have supported around 6-12 inches of snow, which occurred over portions of northeast Arkansas, southern Missouri and northwest Tennessee.

By 2000, ice pellets changed over to light snow (reference surface observations in Table 1) as cold air aloft continued to filter in and the inversion eroded. Between 1800 on the 22nd and 0600 on the 23rd, low pressure raced northeast into southeastern Ohio (Figure 9) as the upper jet nosed into West Virginia with the core of the jet over the Tennessee Valley. Light snow ended in the Memphis area midnight local on the 23rd as the 700mb trough passed east of the area. However, Arctic air sat in place over the Mid-South for the next couple of days which allowed ice and snow on the ground to persist. By the time precipitation stopped falling, Memphis had picked up 2 inches of ice and snow. With very little snow and ice removal equipment in western Tennessee, conditions for transportation remained hazardous through Christmas Day.

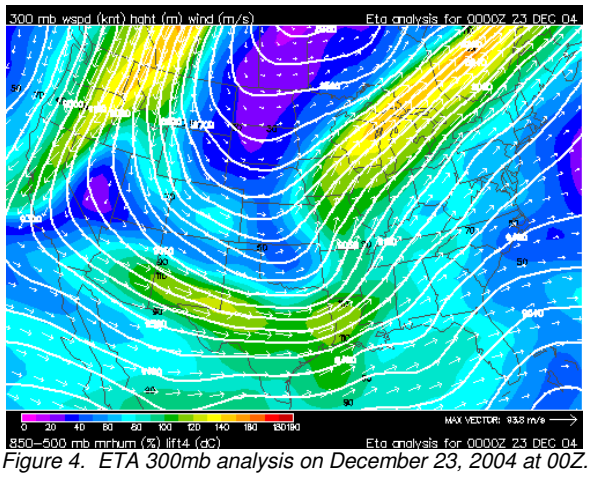

Figure 4. ETA 300mb analysis on December 23, 2004 at 00Z.

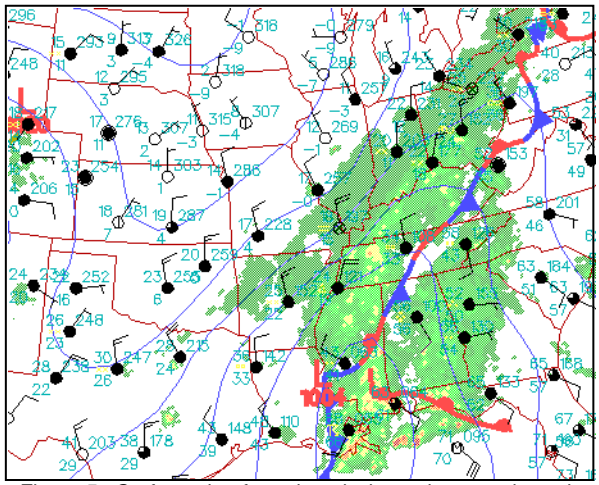

Figure 5. Surface plot, frontal analysis, and composite radar on December 23, 2004 at 00Z.

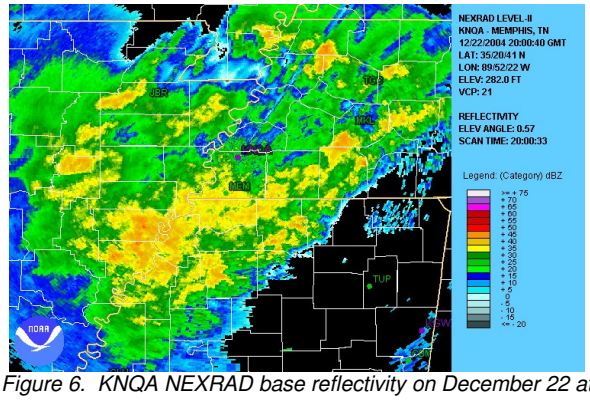

Figure 6. KNQA NEXRAD base reflectivity on December 22 at 2000Z (1400 LST). Note the moderate reflectivity over the airport, which was falling as moderate freezing rain and sleet.

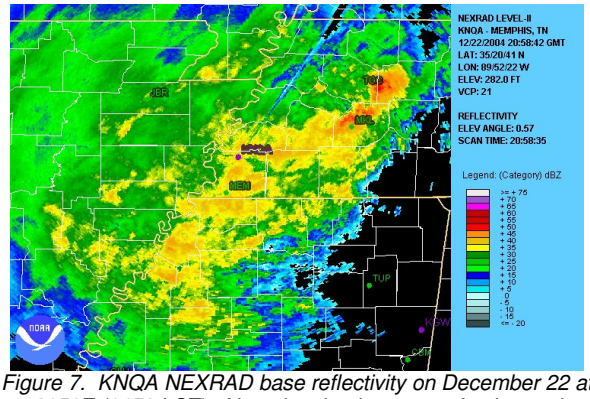

Figure 7. KNQA NEXRAD base reflectivity on December 22 at 2058Z (1458 LST). Note the circular areas of enhanced reflectivity surrounding the radar (KNQA).

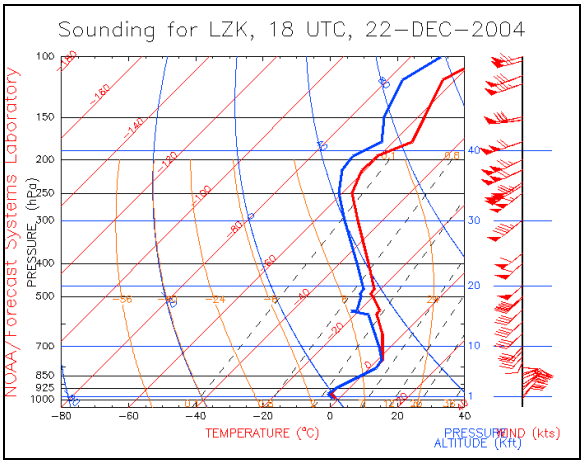

Figure 8. Skew-T sounding from KLZK (Little Rock, AR) on December 22 at 18Z.

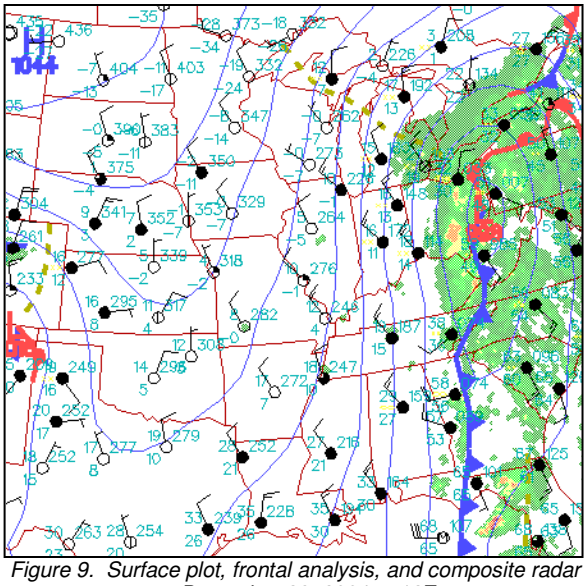

Figure 9. Surface plot, frontal analysis, and composite radar on December 23, 2004 at 12Z.

4. IMPACT ON AIR OPERATIONS

The impact to FedEx's airline operations was significant not only because of the winter weather in MEM, but also due to heavy snow that occurred in IND as a result of the same system. FedEx's Regional Operations Center (ROC) at IND processes the second greatest number of aircraft and packages in the global system, behind only MEM. In the end, IND ended up with over nine inches of snow beginning late on December 21st and ending in the morning hours of the 23rd. The heavy snow caused further complications as decisions were made on system recovery.

4.1 Overview

FedEx operates two banks, or "pushes," of aircraft each day from its Memphis hub. One, described above, involves around 150 aircraft flying into MEM from 2230-0130 local time and departing between 0230 and 0430 (night sort). The second bank of aircraft begins arriving in MEM starting around 0700 and culminating by 1300 and departs from about 1430-1730 (day sort). This particular weather event began near the end of the dayside arrival bank, meaning most planes were on the ground in Memphis and shipments were being unloaded, sorted, and re-loaded onto outbound jets. The timing of the precipitation was terrible given that most planes were in their gates in Memphis and were being coated with freezing rain. Had the event come several hours earlier, many aircraft would not yet have made it to Memphis and could possibly have diverted to alternate airports, or possibly not even taken off from their origin points in the first place. In the end, the worst precipitation occurred during the time when the planes are all scheduled to be sitting in Memphis (see Figure 10).

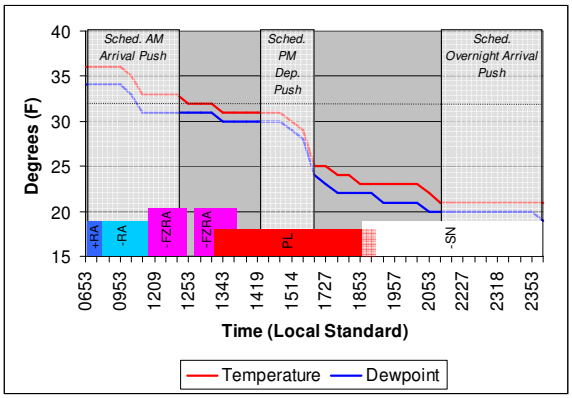

Figure 10. Weather events on 12/22/2004. Temperature and dewpoint are plotted in red and blue solid lines, respectively, as a function of time. Precipitation is shown along the bottom of the graph by the colored bars (height of the colored bars are immaterial). Scheduled FedEx pushes are also indicated.

4.2 Cancellations and Delays

It is rare that FedEx cancels a flight, more often than not simply delaying the aircraft if maintenance or weather events prevent a timely departure. However, with this event, canceling flights became necessary as aircraft and ground equipment were frozen up by the wintry precipitation. Almost all aircraft that did manage to operate incurred a significant delay. Table 2 shows the number of cancelled flights at MEM from December 22-24.

Date	Aircraft Bank	Cancellations
12/22/2004	Day Outbound	45
12/23/2004	Night Inbound	66
12/23/2004	Night Outbound	87
12/23/2004	Day Inbound	98
12/23/2004	Day Outbound	45
12/24/2004	Night Inbound	39
12/24/2004	Night Outbound	12
12/24/2004	Day Inbound	23
12/24/2004	Day Outbound	5
Total Cancellations		**420**

Table 2. FedEx cancellations at MEM, 12-22-04 to 12-24-04

Table 3 shows the number of flights that operated during each aircraft bank, the number that were delayed (regardless of the reason), the number delayed due to weather, and the average weather delay for those that were delayed by weather. It should be stated that the root cause of the weather delay is not given in this table; however, it is safe to assume that due to the magnitude of the event in MEM, the majority of the lengthy weather delays were attributable to the winter storm in Memphis. It is interesting to note that the number of flights that operated from the daytime outbound bank on the 22nd through the inbound bank on the night of the 23rd was well below normal, which is a direct result of the high number of cancelled flights. Normally, about 150 aircraft arrive and depart in the overnight hours and just over 100 operate on the dayside operation. In fact, there was not a dayside inbound bank on the 23rd due to

approximately half of the Memphis gates already being occupied by aircraft that were not able to depart over the preceding 24 hours. In addition, the length of the weather delays, particularly for departures, speaks to just how big of an impact weather had on the FedEx operation. The average departure delay for outbound flights listed in the table was almost four and one-half hours.

Figure 11 depicts the planned and actual departure rate at MEM for Wednesday afternoon (after the winter storm had commenced). As the graph shows, approximately 100 aircraft are scheduled to depart between 1400 and 1800 local time. Even with a de-ice plan in place under "normal winter conditions," twenty planes an hour can depart and all aircraft have departed in about the same time period. However, on this day, only 13 aircraft departed in that five hour period, with another twenty leaving over the next seven hours, stretching well into the night. The aircraft that leave the hub in the afternoon are the same aircraft that are scheduled to arrive back into MEM that night, so one can see how maintaining system form was nearly impossible. Figure 12 shows the same information as Figure 11 (planned versus actual departures) for the early Thursday departure push. Once again, departures were spread over a much larger window, with only 9 aircraft off the ground at 0500 local time (versus a plan of 74).

Date	Aircraft Bank	Total Flights	Flights Delayed	Delayed by Weather	Avg. Weather Delay (hh:mm)
12/22/2004	Day Inbound	112	108	20	0:34
12/22/2004	Day Outbound	59	57	48	7:09
12/22/2004	Night Inbound	83	75	44	1:47
12/23/2004	Night Outbound	61	61	60	5:39
12/23/2004	Day Inbound	1	1	0	0:00
12/23/2004	Day Outbound	48	41	41	3:29
12/23/2004	Night Inbound	136	118	88	1:22
12/24/2004	Night Outbound	148	148	146	4:21
12/24/2004	Day Inbound	94	92	67	3:00
12/24/2004	Day Outbound	89	88	85	2:38
12/24/2004	Night Inbound	27	20	9	1:06

Table 3. FedEx Express flight delays in/out of Memphis, 12-22-04 to 12-24-04

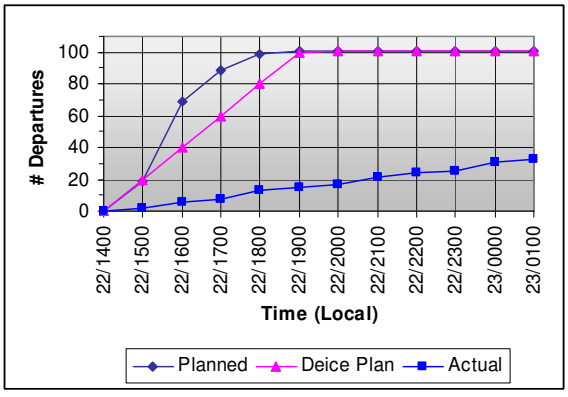

Figure 11. Memphis planned vs. actual departures, Wednesday afternoon/evening (12/22/2004)

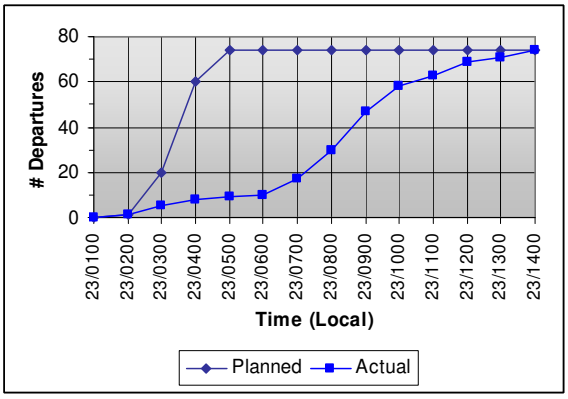

Figure 12. Memphis planned vs. actual departures, Thursday morning (12/23/2004)

4.3 Package Volume

Another aspect of the FedEx operation that reveals the significance of the impacts from this storm is package volume that flowed through the Memphis SuperHub. Table 4 shows the variance in the planned volume versus actual volume for the day and night sorts in Memphis that week. Volume shown includes all FedEx Express and Economy boxes and documents, FedEx freight, and U.S. Postal Service (USPS) Priority and Express Mail. (FedEx has carried much of the Priority and Express Mail for the USPS for the past few years from origin post office to destination post office.) Positive numbers indicate volume above plan and negative numbers represent volume below plan. The table clearly shows the drop-off in volume from the nighttime operation on December 22nd through Christmas Eve, with a significant increase in volume in the initial operations after Christmas, reflecting the high number of cancelled flights after the storm and the

subsequent moving of backlogged volume beginning on the 26th.

Date / Sort	Volume (Plan vs. Actual)
12/22/04 Dayside	-3.7 %
12/22/04 Nightside	-34.7 %
12/23/04 Dayside	-52.6 %
12/23/04 Nightside	-6.3 %
12/24/04 Dayside	-22.4 %
12/24/04 Nightside	No sort
12/26/04 Dayside	144.9 %
12/26/04 Nightside	236.4 %

Table 4. Memphis planned vs. actual package volume. Positive numbers indicate volume above plan and negative numbers represent volume below plan.

The effect of the high number of cancellations and significant departure delays was a decreasing number of available gates at the SuperHub (which is nearly at capacity after a bank of aircraft arrives). In addition, a backlog of package volume in the sorting system was creating gridlock. As the situation deviated further and further from schedule, the flow of information, such as that regarding gates in use and aircraft positions, also was impacted.

5. CONCLUSIONS

In a time-sensitive operation such as the overnight package delivery business, seemingly small events can have a large downstream effect. For example, an aircraft that requires an hour of unscheduled maintenance could end up delaying an entire sort operation at a hub, which in turn could cause many departures from that hub to leave late. The end result is late delivery of a package due to a long chain of events that originally had nothing to do with that package or the path that it traveled from origin to destination. In the case of large-scale events such as the winter storm of December 2004, system recovery can take days.

Though there are many advantages to using a hub-and-spoke network like FedEx's, one of the downfalls is that a shipment from Orlando to Albuquerque may be delayed by events that affect a mid-stream location such as Memphis. The prolonged freezing rain event in Memphis on December 22, 2004 proved to be a major thorn in the side of FedEx's global operation during the busiest week of the year for the company. Flights were significantly delayed and/or cancelled, planes and other ground support equipment (including ramp concrete) was frozen up, and shipments were delayed. However, important lessons were learned that week and in the days and months of "Monday morning quarterbacking" that followed. There are contingency plans for many possible scenarios in the system and those plans were given an excellent test, and further refined, during and after the storm. It will definitely be a case that will go into the annals of FedEx.