AGGREGATE STATISTICS OF THE NATIONAL AIRSPACE SYSTEM

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Abstract

In this paper, we conduct a high-level review of aggregate statistics of the National Airspace System (NAS). First, we identify states, control actions, and performance measures that best characterize the NAS. Then, the most readily available data sources are identified. To provide a working familiarity with the data, descriptive statistics are applied to the most relevant data from the period January, 2000 to October, 2002. We identify weekly, monthly, or seasonal trends that reveal illuminating properties of the NAS. Histograms, comparison plots, and geographic plots are used to visually display the NAS statistics. Geographical concentration of traffic flow management initiatives show regions regularly afflicted with demand-capacity imbalances. Lastly, we conduct a careful study of special event days. It is well known that holidays and catastrophic events can have a severe impact on local traffic conditions. But only some of these have an impact on nation-wide traffic. Moreover, the ramifications are often observed just prior to, or just after an event. We examine a variety of special events for magnitude and temporal scope of impact. We do not make any conclusions about how well or efficiently the NAS is working on any given day.

Introduction

There is a myriad of aviation related data available to the researcher. Yet, in general, each datum can be placed into one of five categories (**Figure 1**). In this decomposition, we focus on an enumeration of variables that describe the NAS. This does not imply that all these variables are the necessary nor sufficient variables to investigate a macroscopic model of the NAS.

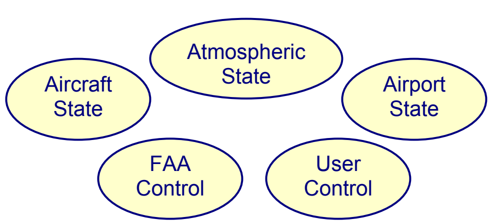

Figure 1: NAS Data Categories.

Atmospheric States – There are several atmospheric states that influence the NAS; they include, but are not limited to: Winds aloft, Precipitation, Convective Activity, Cloud Tops, Ceiling, Visibility, Temperature, Turbulence (Light, Moderate, Severe, Extreme), Icing (Rime, Clear), and Volcanic Ash.
Aircraft States – NAS state variables that describe aircraft include, but are not limited to: Aircraft Type / Call Sign, Arrival/Departure Airports, Aircraft Class – (Small, Large, B757, Heavy), Airline Operator, Flight Plan, Track, Flight Rule Category (Instrument Flight Rules (IFR) or Visual Flight Rules (VFR)), and Emergency State (Lifeguard).
Airport States – Airport states that influence the NAS include, but are not limited to: Airport Arrival Rate (AAR), Airport Departure Rate (ADR), Runway Configuration, Airport Location, De-icing Status, Runway Visibility Range (RVR), Airport Category / ILS Category (I, II, IIIa, IIIb, IIIc), and Gate Availability.
FAA Controls – FAA control actions[1,2] include: Ground Delay Programs (GDPs), Ground Stops (GSs), Miles-In-Trail (MIT) restrictions, Approval Requests (APREQs), Direct To Routes, Vectors (Speed, Altitude, Heading) for spacing or conflict avoidance, Airborne Holding (Circular, Path-Stretch), Playbook Plays (Re-routes; Coded Departure Routes (CDRs)), Capping or Low Altitude Arrival and Departure Routes (LAADRs), and Special Use Airspace (SUA) (de)-activation.
User Controls – User controls (Pilot and/or Airline Operational Control (AOC)) include: Flight Cancellations, Altitude Changes for Turbulence Avoidance, Direct To Routes for User Route Preference, Vectors (Speed, Altitude, Heading) for Weather Avoidance, and Vectors (Speed, Altitude, Heading) for Terrain Avoidance.

In addition, there are also performance metrics that describe the NAS. While many performance metrics exist, the emphasis is on delay metrics.

- Gate Departure Delay – Ground holds, ground stops, or other delays incurred at the gate.
- Taxi Out Delay – Queuing delays due to restrictions in the airport departure capabilities.
- Take Off Delay – The Gate Departure Delay plus the Taxi Out Delay.

- Airborne Delay – The difference between the scheduled and measured airborne time. The scheduled airborne time is the estimated time en route that is filed by the airline that is contained in the Enhanced Traffic Management System (ETMS) FZ message.
- Landing Delay – The take off delay plus the simulated airborne delay.
- Taxi In Delay – Queuing delays due to restrictions in the airport arrival capabilities.
- Gate Arrival Delay – The difference between the scheduled arrival time and the actual arrival time.
- Block Time Delay – Block time is the time between gate arrival and gate departure. Block time delay is the gate arrival delay minus the gate departure delay.

In this paper, we are not able to review all these NAS states, controls, and performance metrics. However, we present a cross section of these in order to characterize the behavior of the NAS.

Data Sources

The following data sources were used in this study.

ASPM Data – The FAA's Aviation System Performance Metrics (ASPM) data records flight metrics at 50 major airports. ASPM data includes: scheduled and actual departures and arrivals, cancellations, gate delays, taxi-in and taxi-out delays, airborne delays, block time delays, meteorological conditions, ceiling, visibility, temperature, runway configuration, airport departure and arrival rates, and other data.

ATCSCC Log Data – Data from the Air Traffic Control System Command Center (ATCSCC, Herndon, VA) logs were collected for: MIT restrictions, GS, and GDP data. Data are recorded only when a facility contacts the ATCSCC to report the restriction, which is only a subset of all the control actions taken in the NAS. When restrictions are imposed internal to a center without affecting other neighboring centers, it is not required to report such restrictions to the ATCSCC.

BTS Data – Bureau of Transportation Statistics (BTS) data are for domestic and international air travel from the 10 largest airlines. These airlines generate over 90% of domestic operating revenues. Because each airline earns at least 1% of the total domestic scheduled passenger revenue, FAA regulations require them to report on-time performance data to and from the 27 largest airports.

ETMS Data – ETMS records for all IFR flights, including air carrier, cargo, air taxi/commuter, GA, and military operations; ETMS also covers arrivals of international flights. ETMS receives NAS state messages such as: scheduled flight plans, scheduled flight cancellations, flight plans, flight plan amendments, cancellations, activation of a departure, center boundary crossings, position updates, and activation of an arrival.

OPSNET Data – Air Traffic Operations Network (OPSNET) data covers all flights in the NAS for air traffic activity at Air Route Traffic Control Centers (ARTCCs) and preliminary airport traffic counts, instrument operations and instrument approaches, as well as delays. Air traffic activity is the total of the number of operations at FAA and contractor controlled airports, instrument operations at FAA and contractor controlled airports, and aircraft handled at ARTCCs. A flight is under FAA control from the time the aircraft leaves a departure gate to when it arrives at an arrival gate. All OPSNET data are aggregate and not flight-specific. Delays are measured with a 15-minute threshold (elapsed flight time exceeds the flight plan time filed with the FAA by 15 minutes). Delays are recorded for the time the aircraft is at the gate, on a taxiway, or holding en route. International delays are also recorded.

Notation

Figure 2 illustrates the notation that is implicitly used throughout this report to describe the statistics within graphics. The variable μ defines the mean, and σ defines the standard deviation.

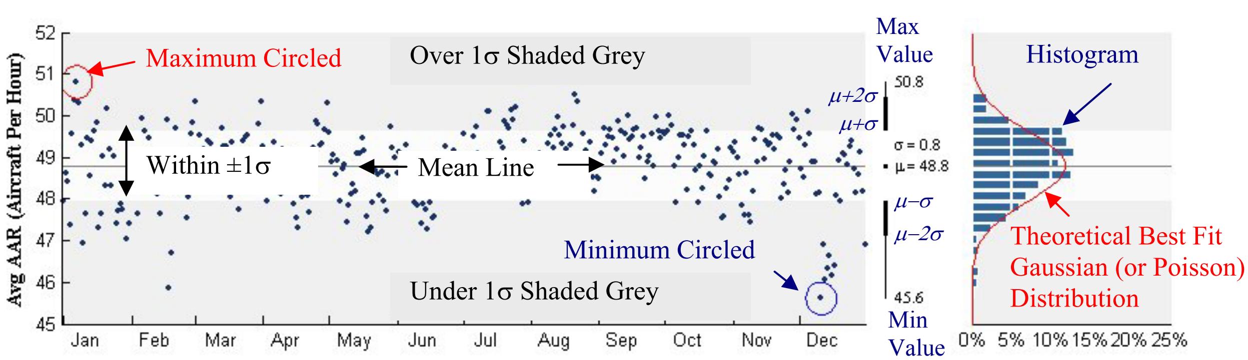

Figure 2. Notation used in statistical plots.

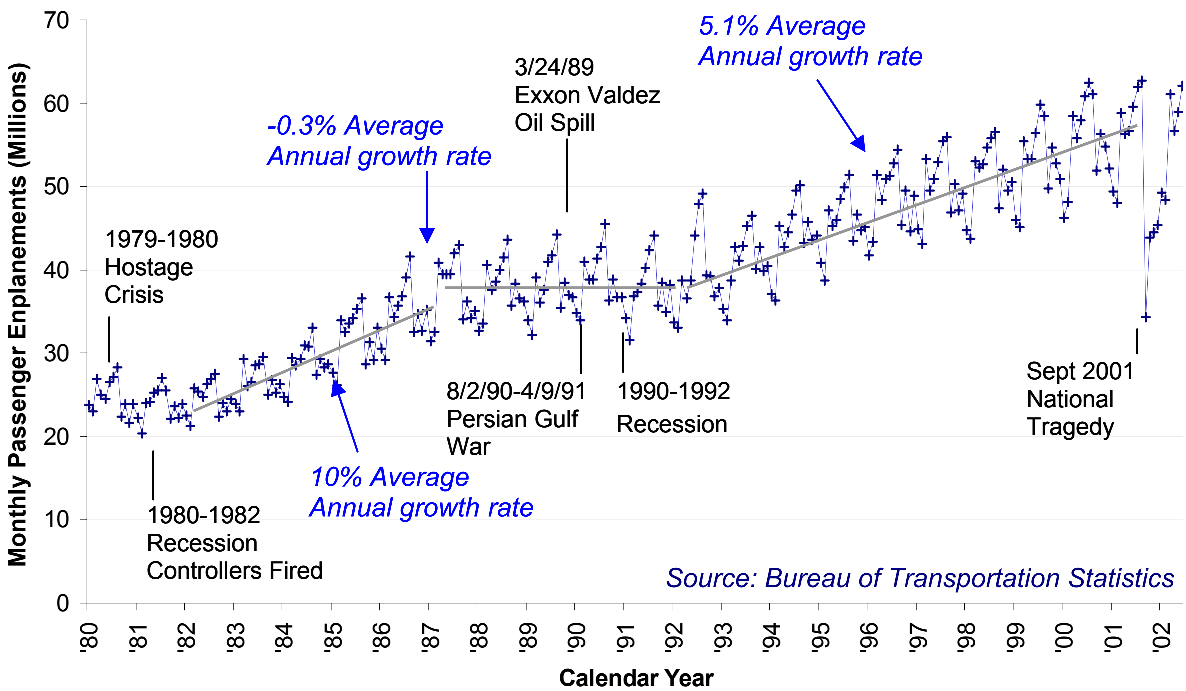

Figure 3. Historical Timeline for Domestic Enplanements.

Statistical Analysis of the NAS

A useful point of departure for discussing data for the NAS is to consider the number of domestic enplanements as shown in **Figure 3**. Clearly, the NAS shows long-term periods of growth that have been greatly disrupted by the Sept. 11, 2001 tragedy. The recovery rate from Sept. 2001 to date exceeds the historical growth rate over the last decade.

1.0 NAS States

1.1 Seasonal Trends in Enplanements

BTS provides statistics of the monthly total number of enplanements for both domestic and international air travel. We investigate domestic travel only. Domestic revenue passenger enplanements record the total number of passengers boarding an aircraft in the NAS. These data are reported monthly for the years 1980-2002 in **Figure 4**. Enplanement data provide evidence of a seasonal trend in demand.

1.2 Weekly Trends

It is common knowledge within the air traffic community that air travel is heavier during the week than on weekends. Scheduled arrivals and departures defined by OAG data from ASPM generally demonstrate the tri-modal distribution of Saturday, Sunday, and Weekday traffic. This is easily verified by collecting departure and arrival counts by day of week (Monday, Tuesday, Wednesday, etc.). **Figure 5** shows that average departure and arrival counts are significantly less on Saturdays (14.8% less) and Sundays (8.96% less) than on weekdays. Also, traffic volume is fairly uniform across individual days of the week.

1.3 Average Airport Arrival Rates (AARs)

AARs are determined from ASPM data. **Figure 6** illustrates the AAR distribution for the 50 ASPM airports for 2000 to date. The distribution of the AARs at these airports is approximately normal, with an average rate of about 49 aircraft per hour. At the extreme, Dallas – Ft. Worth leads the NAS with yearly averages that range around 134 aircraft per hour.

1.4 Airport Approach Conditions (IFR vs VFR)

ASPM provides data to describe the meteorological conditions at airports. VFR signifies a visual approach condition at the airport, while IFR indicates that there were instrument approach conditions at the airport. IFR and VFR conditions were recorded in ASPM for every quarter hour at each airport. The total number of 15-minute periods over all airports with IFR and VFR conditions recorded were counted and used to compute the percentage of IFR vs. VFR conditions for each day. **Figure 7** shows the percentage of IFR and VFR conditions occurred every day over all ASPM 50 airports for the year 2000.

1.5 Airport Visibility Conditions

ASPM provides data to describe the visibility conditions at airports. **Figure 8** indicate the visibility conditions for the ASPM 50 airports for 2000. Visibility conditions generally degrade in the winter months as more airports experience overcast skies for long durations of time.

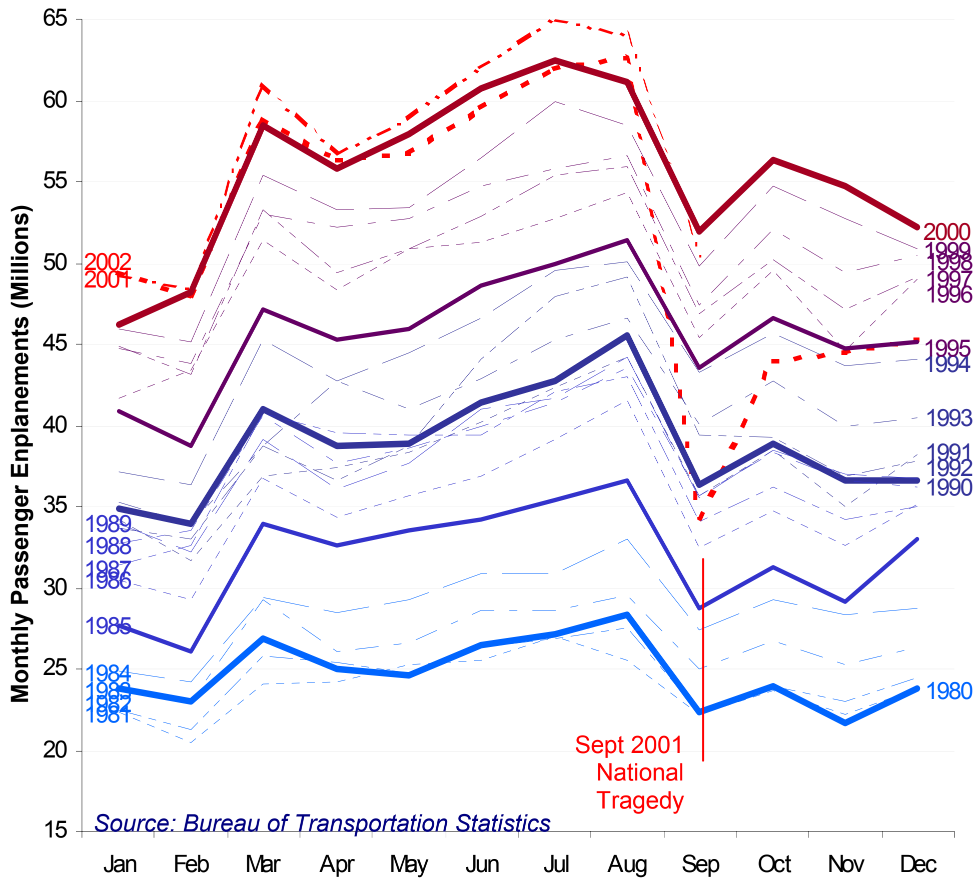

Figure 4. Comparison of yearly data for Domestic enplanements identifies seasonal trends.

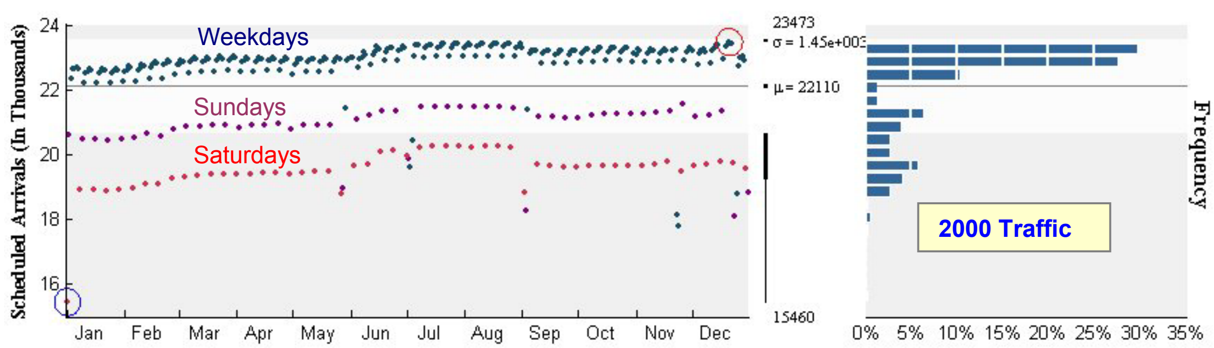

Figure 5. Comparison of traffic based on day of week for 2000.

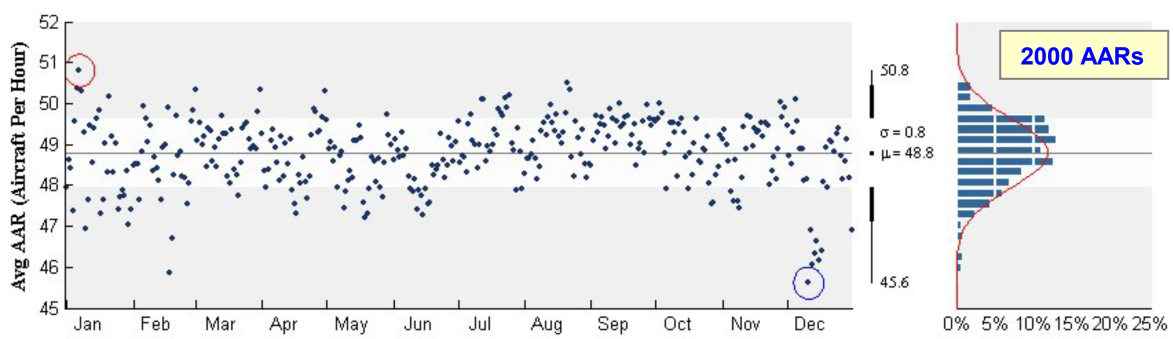

Figure 6. Distributions for airport reported arrival rates for domestic flights in 2000.

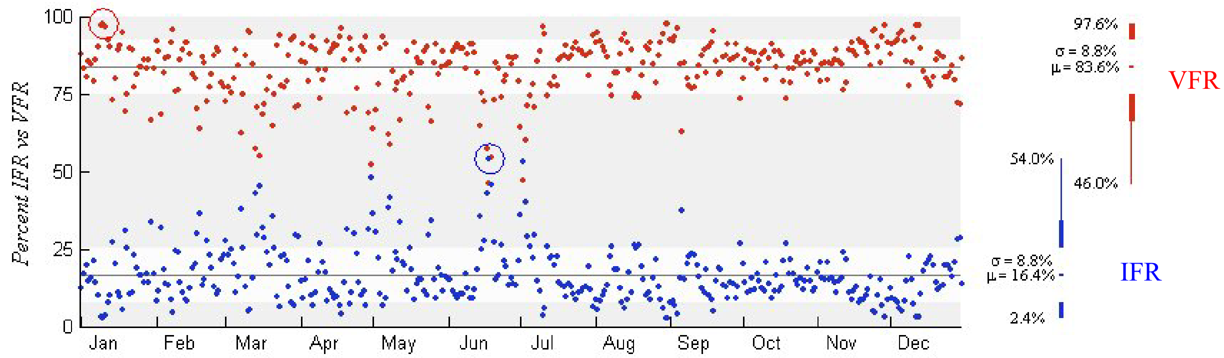

Figure 7. Average IFR vs. VFR conditions for 2000.

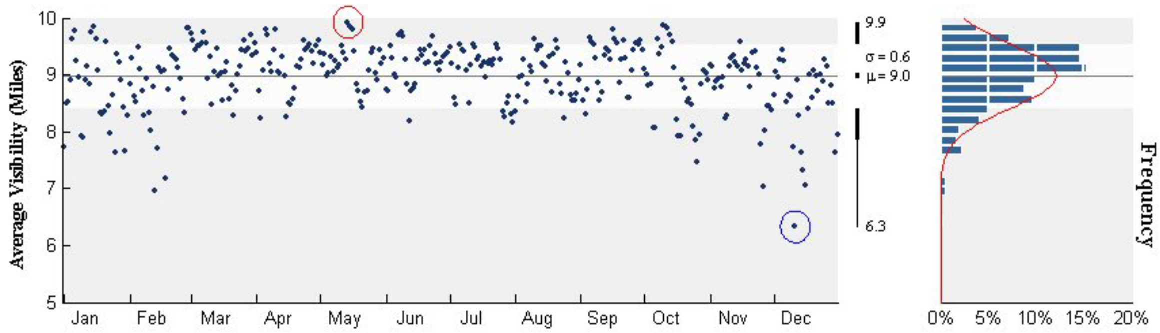

Figure 8. Average visibility conditions for 2000.

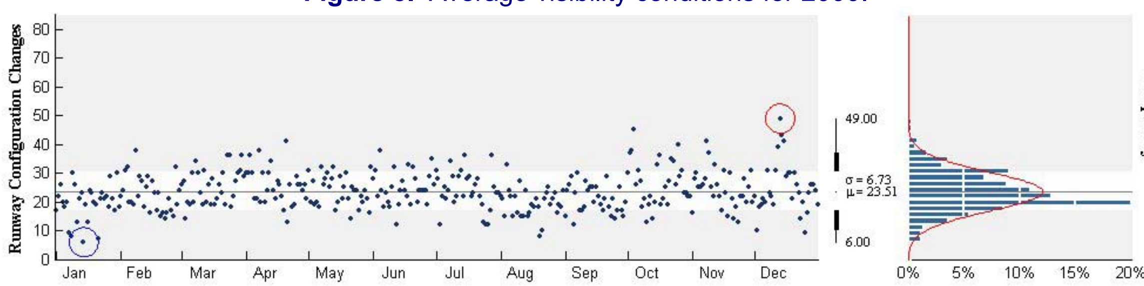

Figure 9. Average number of runway configuration changes for 2000.

1.6 Runway Configuration Changes

As shown in **Figure 9**, ASPM provides data describing the total number of runway configuration changes for ASPM 50 airports. While not a direct measurement of weather conditions, this statistic is highly linked to wind speed and direction. Additionally, it is linked to traffic demand. Runway configuration changes were fairly constant for 2000.

2. 0 NAS Controls

2.1 Ground Delay Programs

During a GDP, the arrival flow rate into an airport with a capacity shortfall (or abundance of demand) is reduced to avoid inundating the airport with more arrivals than it can safely accommodate. Arrival demand is brought in line with arrival capacity by creating a virtual queue of arrival slots. The number of slots in any given hour corresponds to the estimated number of aircraft that the airport can land. Each aircraft estimated (or scheduled) to arrive during the GDP time horizon is assigned to an arrival slot (time interval). From this Controlled Time of Arrival (CTA), a Controlled Time of Departure (CTD) is computed for each aircraft by subtracting the estimated flying time. The difference between the CTD of a flight and the estimated arrival time just prior to implementing the GDP is the amount of FAA-issued ground delay that flight must absorb. The net effect of a GDP is to transfer anticipated airborne holding back onto the ground.

There are many reasons why a GDP might be run. Sometimes, traffic flow into an airport is reduced to slow down the flow through an unrelated piece of airspace. Other times, there is an unusually large arrival demand that exceeds normal AARs. But most of the time, a GDP simply reflects deterioration in airport conditions. Weather is the most frequent culprit. Thus, frequency and magnitude of GDPs make a strong statement about NAS conditions. A simplistic metric of GDPs is how many are being run on a given day. This gives a rough indication of how many airports are in a state of demand-capacity imbalance. A typical day in the NAS might have 1 or 2 GDPs in place, while 5 or more GDPs indicates NAS-wide problems.

GDP data were collected from the ATCSCC Logs. **Table 1** shows aggregate GDP data across the NAS for the years 1998 through 2001. These data indicate an increase in the use of GDPs each year. There are certain airports for which GDPs are issued more than others. These airports are: ATL, BOS, EWR, LAX, LGA, ORD, PHL, and SFO. The three leading airports where GDPs are issued (based on 2000 and 2001 data) are: SFO, LGA, and ORD.

Table 1. GDPs issued during 1998 - 2002.

Year	Number of GDPs	Average per Day
1998	513	1.4
1999	705	1.9
2000	1083	3.0
2001	799	2.8*
2002	615	1.7

Note: * 2001 ave. is determined using Jan.-Aug. (243 days).

Figure 10 illustrates the geographic distribution of GDPs. The areas of the circles at each airport are proportional to the number of GDPs at the respective airport. As illustrated, GDPs are concentrated at the major hub airports, SFO, and in the northeast corridor. This spatial distribution does not change much year to year.

2.2 Cancellations

Departure cancellations occur in two groups, one cluster of cancellations around 15 hrs and one about 2 hrs prior to departure. Although the airlines may submit cancellations days or even weeks before departure, the airline Collaborative Decision Making (CDM) data is not synchronized with ETMS data until 15 hours before the departure time. Thus, the cancellations that cluster at roughly 15 hrs prior to departure represent cancellations of flights that are not scheduled to take off. These cancellations account for approximately 38% to 40% of cancellations. The cancellations that occur within 2 hrs of take off are generally in reaction to weather, a schedule conflict, or mechanical problems. These can also occur after the scheduled departure times.

One can track the daily cancellation statistics to note trends. To illustrate this point, **Figure 11** and **Figure 12** illustrate the cancellation statistics as a storm system develops and moves across the NAS.

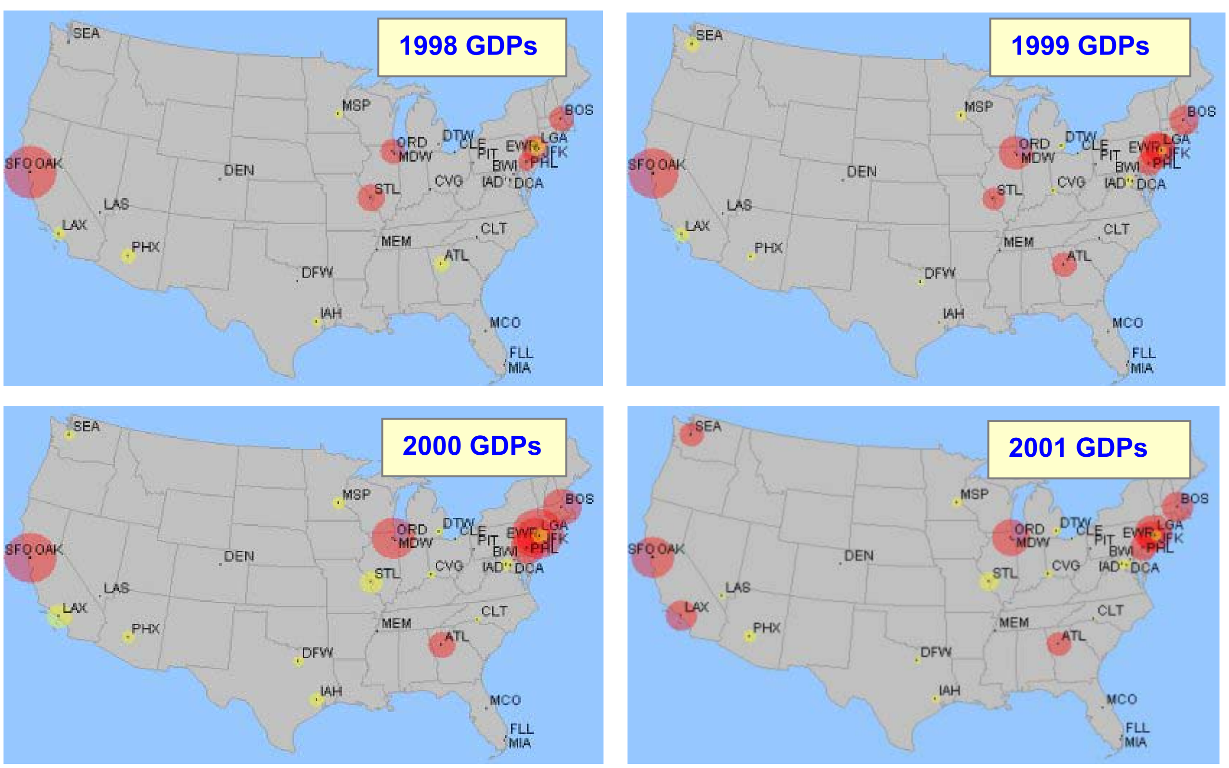

Figure 10. Geographical location of airports (and magnitude) of GDPs for 1998-2001.

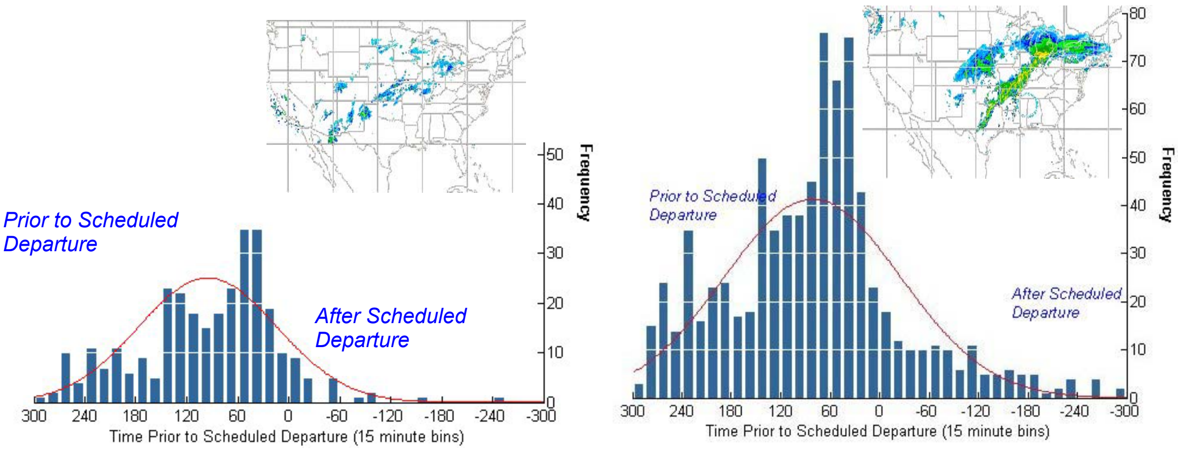

Figure 11. Cancellation times relative to scheduled take off time prior to a major storm on Jan. 29, 2002 (left) and during a major storm Jan. 31, 2002 (right).

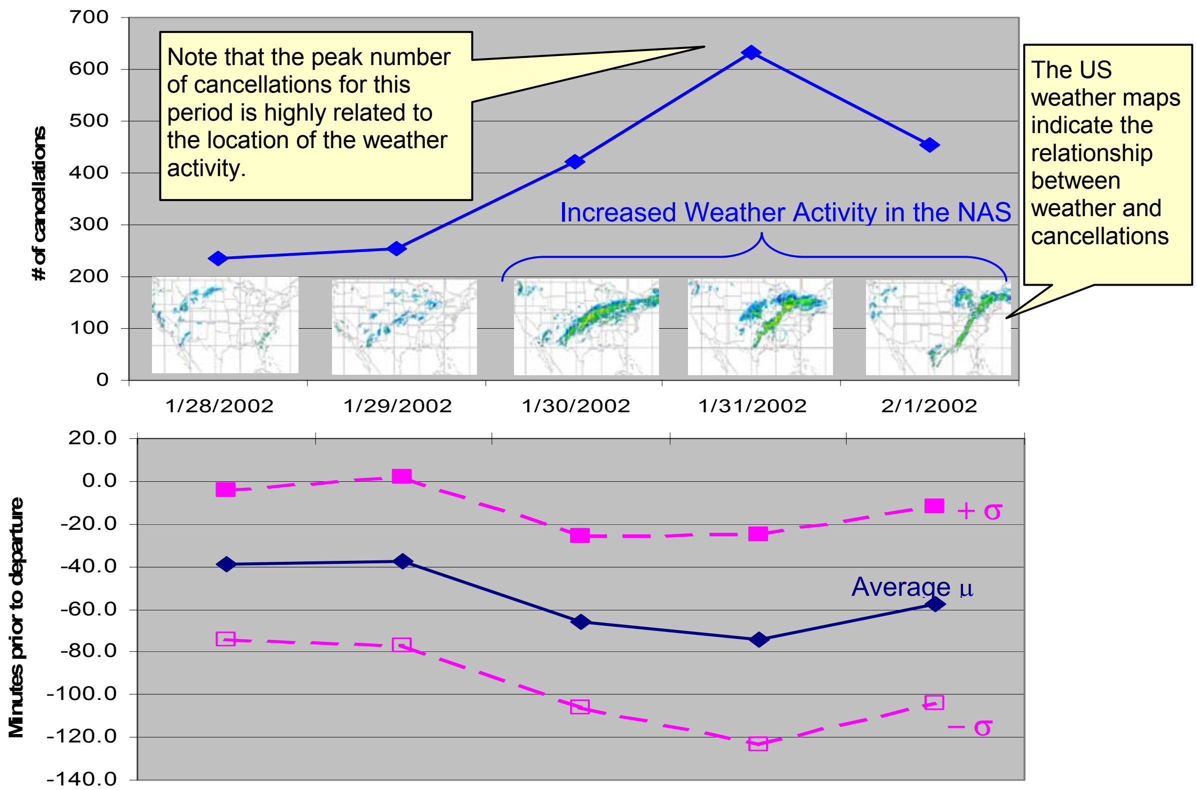

Figure 12. Cancellation statistics as they vary from Jan. 28 – Feb. 1, 2002.

2.3 Ground Stops

A Ground Stop (GS) is a traffic flow initiative in which all traffic is banned from departure for a period of specification to a particular airport. This is usually implemented to reduce the flow of traffic in an unexpected situation, such as highly unpredictable convective weather activity. The criterion for inclusion of a GS is based on departure time – unlike a GDP, where the criterion for inclusion is arrival time. For instance, a 11:00Z - 11:30Z GS at ORD means that no flights are allowed to depart for ORD between 11:00Z and 11:30Z. The flights subsequently get effective ETDs one minute after the end of the GS (11:31Z in this case). A GS is usually short-lived, highly tactical maneuver. For this reason, the GS frequency is an indication of unpredictable, disruptive events in the NAS.

GS data were collected from the ATCSCC Log. **Table 2** shows the aggregate GS data across the NAS for the years 2000-2002. **Figure 13** and **Figure 14** depict daily counts for 2000 and 2001. **Figure 15** shows the geographic distribution of GS data across the NAS for 2000 through 2002. An increase during the summer months is primarily resulting from the convective weather season. After Sept. 11, 2001, a drop in the traffic volume occurred across the NAS, and thus, the number of GSs during the remainder of the year was low. A Poisson distribution was assumed for determining the mean and standard deviation for GS data.

Table 2. GSs issued during 2000 - 2002.

Year	Number of GSs	Average per Day
2000	491*	1.8*
2001	955	2.6
2002	1102	3.0

Note: * Due to a lack of data, the 2000 average is determined using April – Dec. (275 days) only.

2.4 MIT Restrictions

Traffic Flow Management (TFM) places MIT restrictions on lines of aircraft traveling in the same direction to control the rate of flow. A MIT of 30 miles means that each aircraft within the flow on a jet route must maintain at least 30 miles of separation between itself and the aircraft in front of it. MIT restrictions are usually placed at the boundary of adjacent sectors or centers to provide the spacing necessary for safe travel with the downstream sector or center. Some MIT restrictions are standard operating procedure. But most of the time, they are indicative of a combination of excessive demand and degraded capacity. Since MIT restrictions often impact more than one center, they are coordinated through and electronically recorded by the ATCSCC. For each restriction, there is a record of the stream of traffic to which it applies, the start and end times of the restriction, and the required spacing.

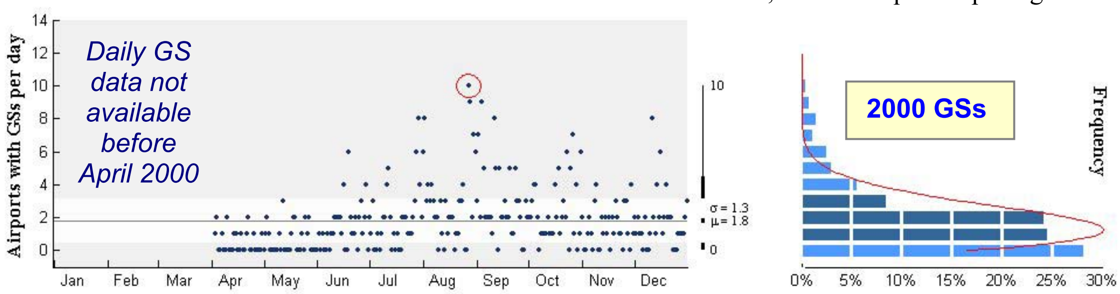

Figure 13. Number of daily GSs that occurred in 2000.

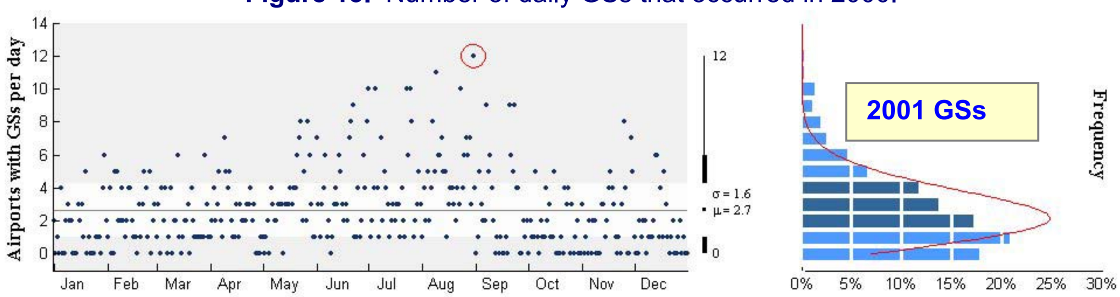

Figure 14. Number of daily GSs that occurred in 2001.

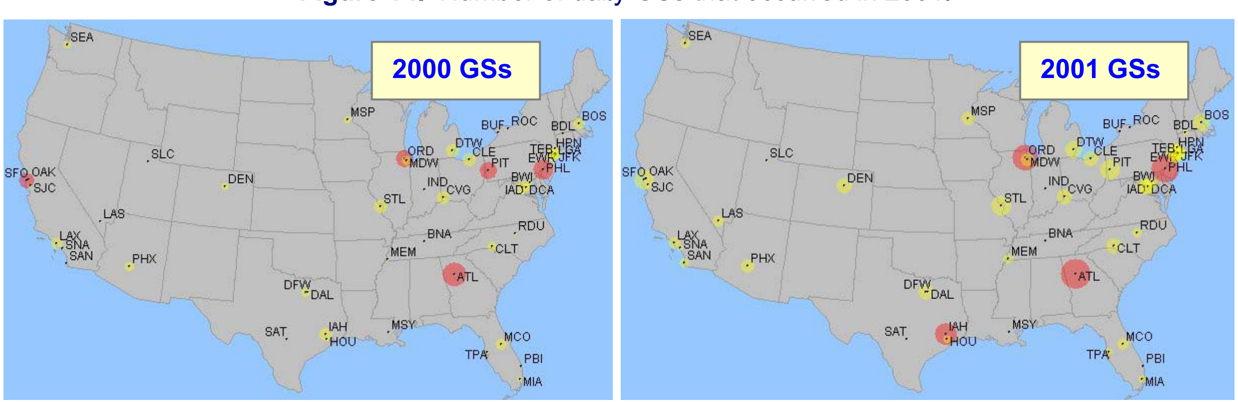

Figure 15. Geographical location of airports (and magnitude) of GSs for 2000-2001.

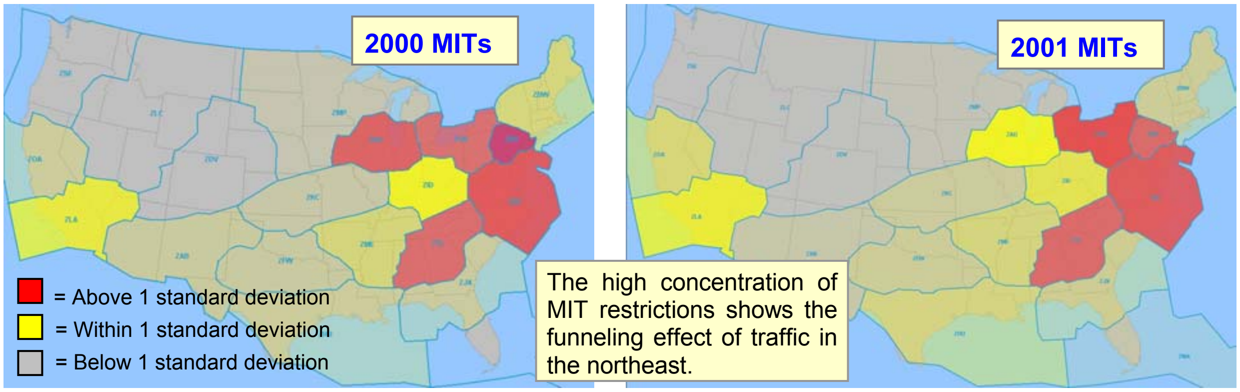

Figure 16. Geographical distribution for the ave. daily number of MIT restrictions per center 2000-2001.

As illustrated in **Figure 16**, the majority of the use of MIT restrictions occurs in the NE corridor, and this is consistent from year to year.

3.0 NAS Performance

3.1 OAG-Based Gate Departure Delay

OAG-based gate departure delays, as shown in **Figure 17**, are based on ASPM data. Gate delay is defined as the actual gate departure time minus the OAG-scheduled departure time.

3.2 Average Airport Departure Delay

Airport Departure Delay is defined as the actual time off, minus the scheduled gate departure time and the unimpeded taxi-out time. **Figure 18** presents the airport departure delay statistics.

3.3 Average Gate Delay

Average Gate Delay statistics, as shown in **Figure 19**, are defined as the actual gate departure times, minus the scheduled gate departure times.

3.4 Average Airborne Delay

ASPM is used to identify airborne delay, as illustrated in **Figure 20**. Airborne delay is defined as the actual airborne time minus the carrier submitted time en route.

3.5 Average Arrival Delay

The average airport arrival delay, as illustrated in **Figure 21**, is the average delay for gate-in, defined as the actual gate-in minus the scheduled gate-in.

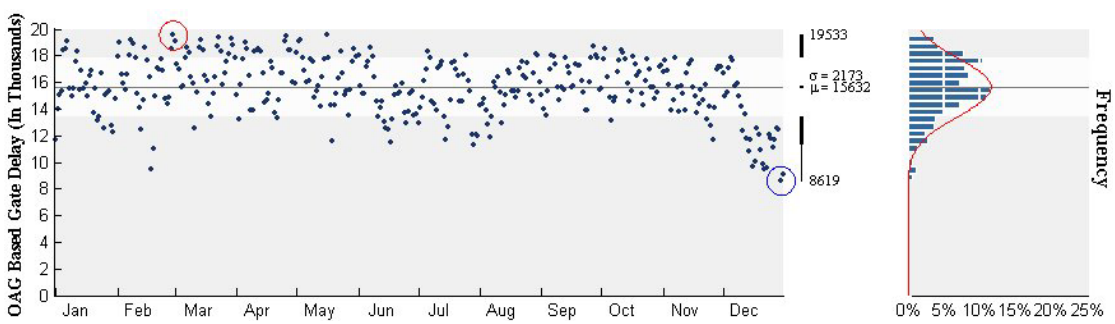

Figure 17. Total minutes of gate departure delay for domestic flights in 2000.

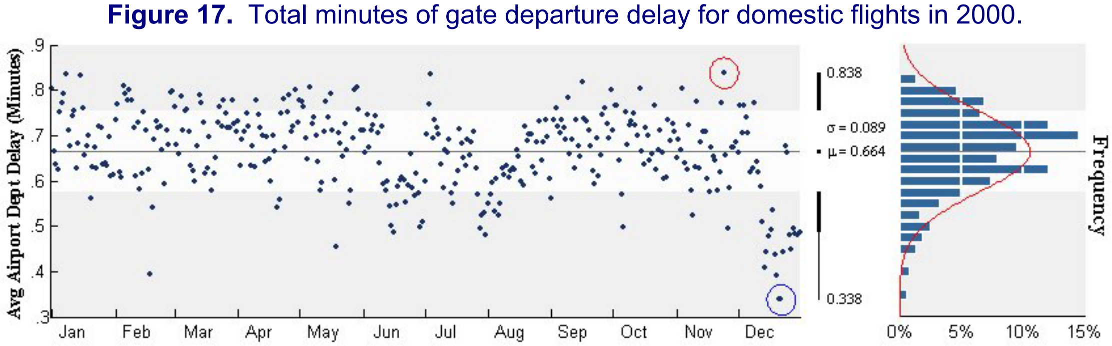

Figure 18. Distributions for airport departure delay for domestic flights in 2000.

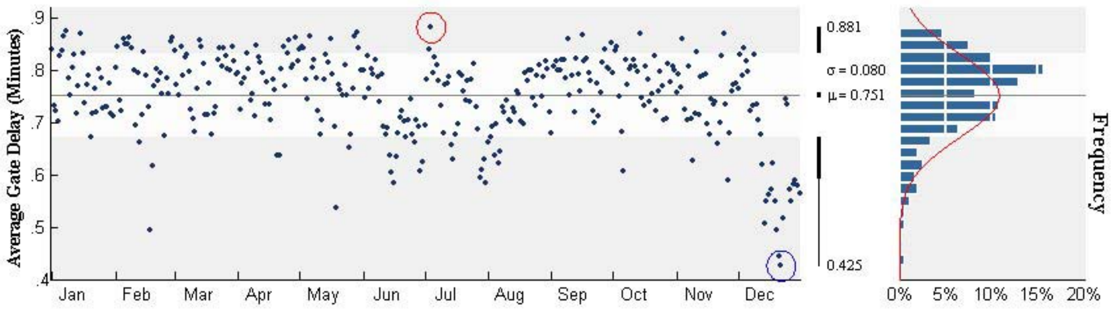

Figure 19. Distributions for airport gate delay for domestic flights in 2000.

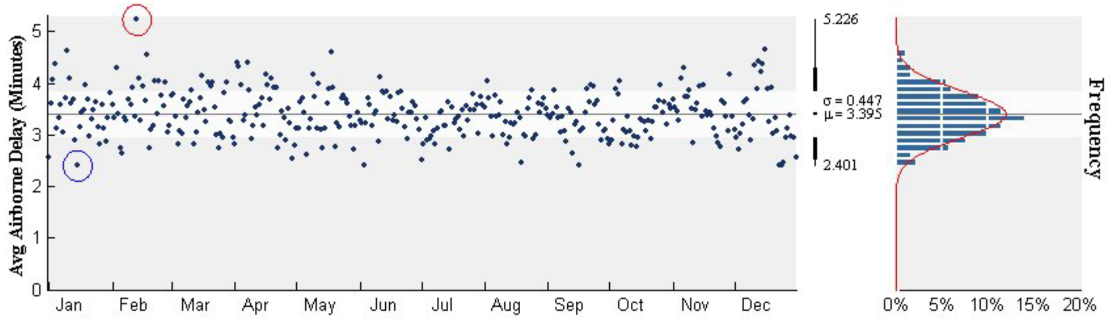

Figure 20. Distributions for airborne delay for domestic flights in 2000.

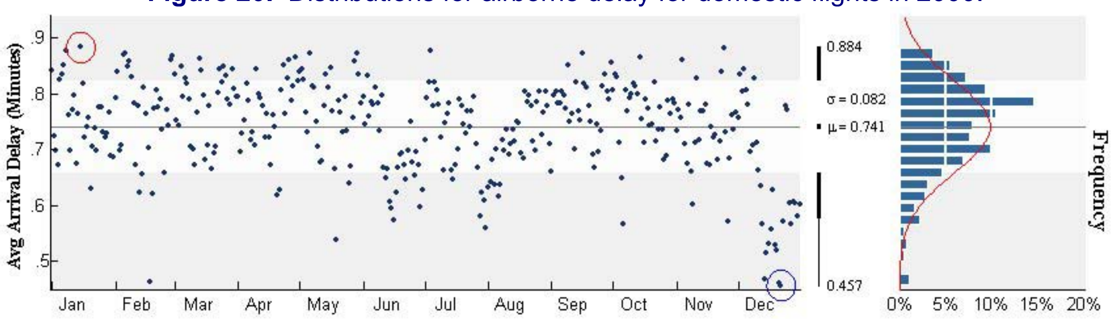

Figure 21. Distributions for average arrival delay for domestic flights in 2000.

3.6 Taxi In and Taxi Out Delay

Total taxi-in and taxi-out delay minutes per day are compared in **Figure 22**. The vast difference in the mean and standard deviation of the two suggests that the root causes are very different. Fundamentally, these differences arise from the fact that there tends to be substantial queuing for departures. This is done in order to keep pressure on the runways as they wait for gaps in the arrival stream that lead to increases in taxi out delays. Departures are subject to more NAS constraints (e.g., MIT restrictions) as well as interactions with arrival flows in terms of sharing runways. By comparison, unless an arrival has to cross the runway or wait for a gate to be available, it usually proceeds nearly directly to its gate at or near an "unimpeded" taxi in time. Thus, the mean is lower and the variance is quite small.

Several reasons explain why some days have taxi out delay on the same order as the taxi in delay. First, depending on the day of the week, the traffic loading may be significantly lower (e.g., Sunday vs. Thursday). Also, depending on the dynamics of the rest of the NAS, the phasing of banking operations at hub airports might be more or less optimal. When there are late arrivals, departures, which might nominally be favored, end up having to wait as the arrivals trickle in. For future research, it might be interesting to look separately at the behavior of hub airports (ORD, DEN) versus a constant pressure airport like LGA.

3.7 Average Block Delay

Block times span gate out to gate in. Block delay is defined as the actual Gate-to-Gate time minus the scheduled Gate-to-Gate time. Block delay statistics are presented in **Figure 23**.

3.8 Total Block Delay

Total delays based on OPSNET data are presented in **Figure 24**. This is a count of operations which have reportable delay based on OPSNET standards.

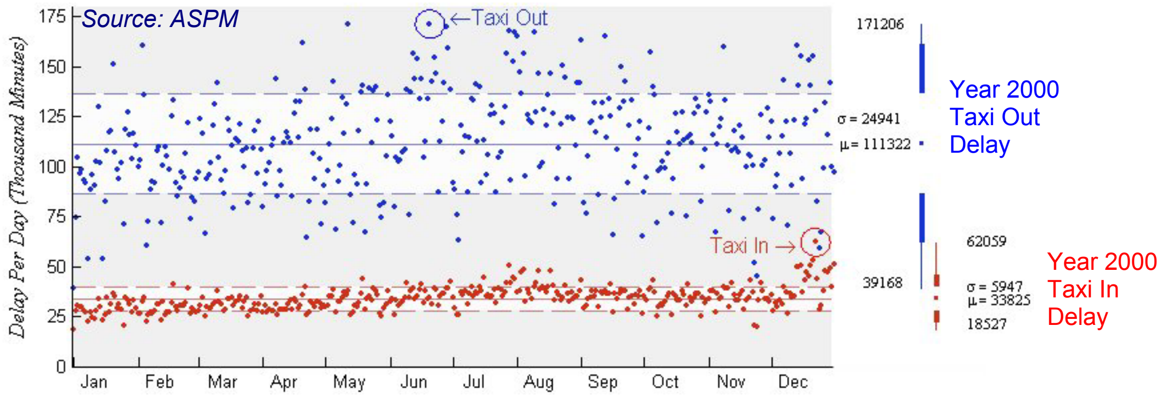

Figure 22. Distributions for taxi-in vs. taxi-out delay for domestic flights in 2000.

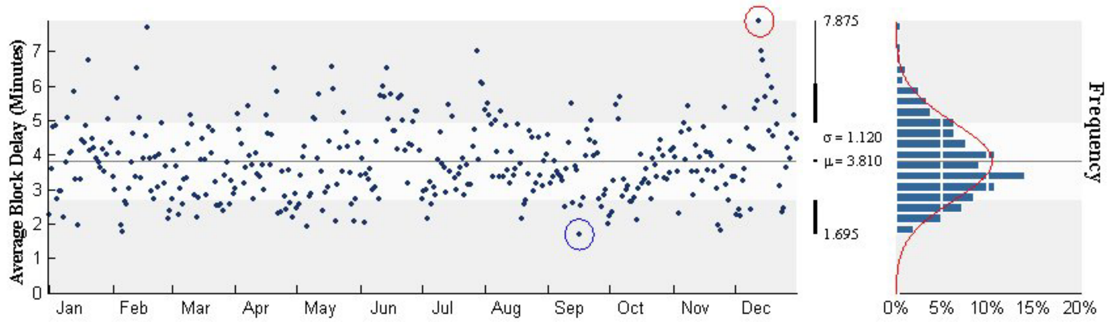

Figure 23. Distributions for block delay for domestic flights in 2000.

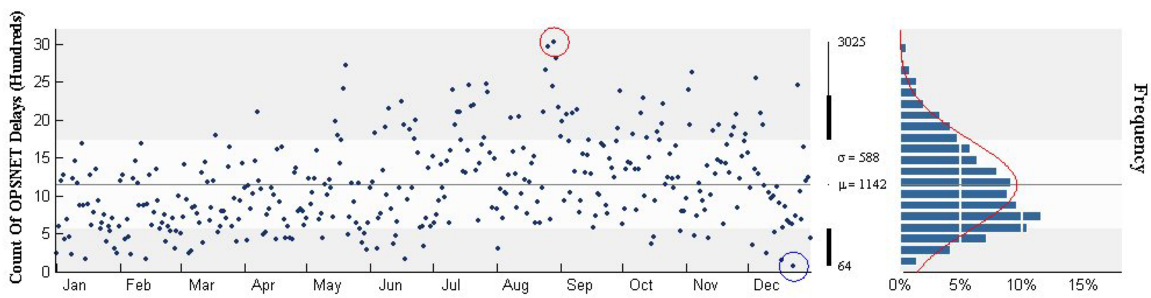

Figure 24. Total delayed operations in 2000.

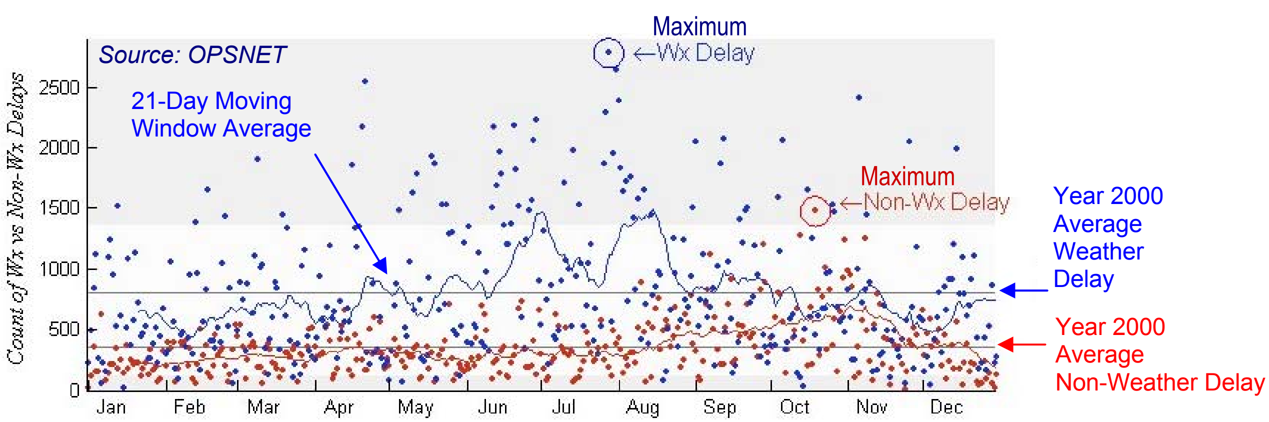

Figure 25. Weather vs. Non- Weather Related Delays in 2000.

3.8 Weather Related Delays

Weather-related delays generally increase during the convective weather season (generally defined from May 15 to September 15). **Figure 25** presents the total number of OPSNET weather related delays for the year 2000 in comparison to non-weather related delays. Note that the average for the year for weather related delays is more than twice the average for non-weather related delays.

Effects of the September 11, 2001 Tragedy

The tragedy of September 11 has such a profound impact on air travel that we would be remiss not to point out some of its major impacts. The most notable impact, of course, is on traffic volume. Data for traffic flow initiatives clearly display a drop in demand after the tragedy. GDP occurrences are reduced, along with incurred delay and GDP minutes (**Figure 26** – **Figure 28**).

The precipitous drop in air traffic volume can also be observed in delay data, (**Figure 28** - **Figure 30**). There are substantial decreases in taxi-out delay, total delayed operations and weather related delays. A certain rate of recovery is also noted. As seen in **Figure 4** above, by the end of 2001 passenger enplanements rebounded to the equivalent of 1995 levels. And by March of 2002, it reached the equivalent of 1998/1999 levels.

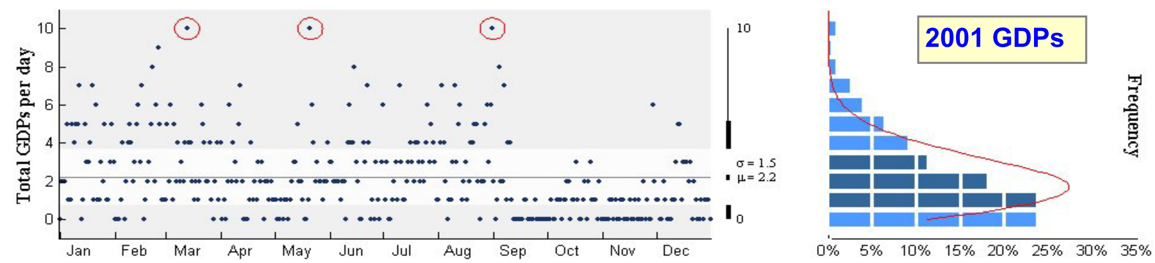

Figure 26. Daily number of GDPs in the year 2001.

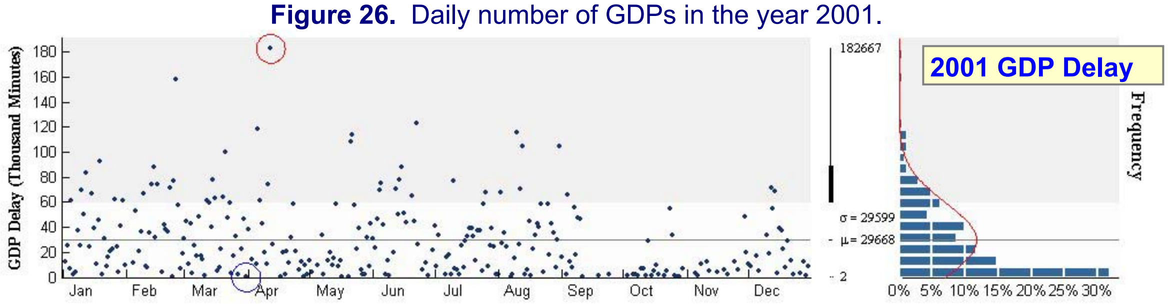

Figure 27. Number of delay minutes due to GDPs that occurred in 2001.

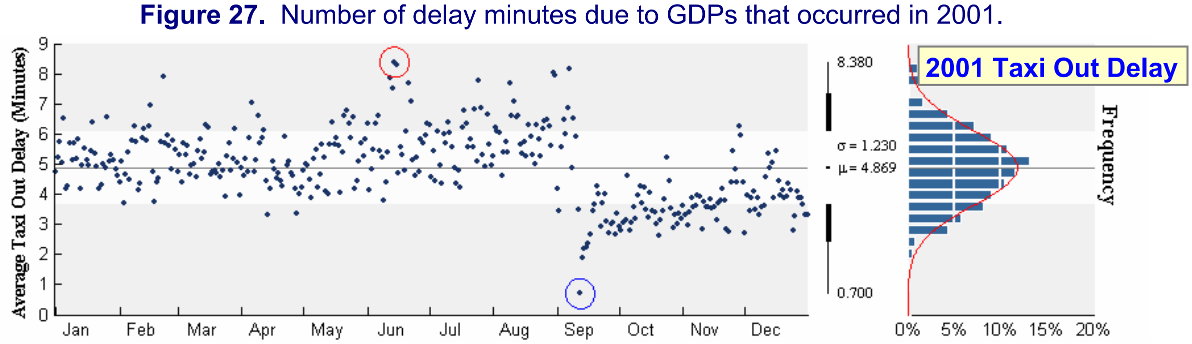

Figure 28. Distributions for average taxi out delay for domestic flights in 2001.

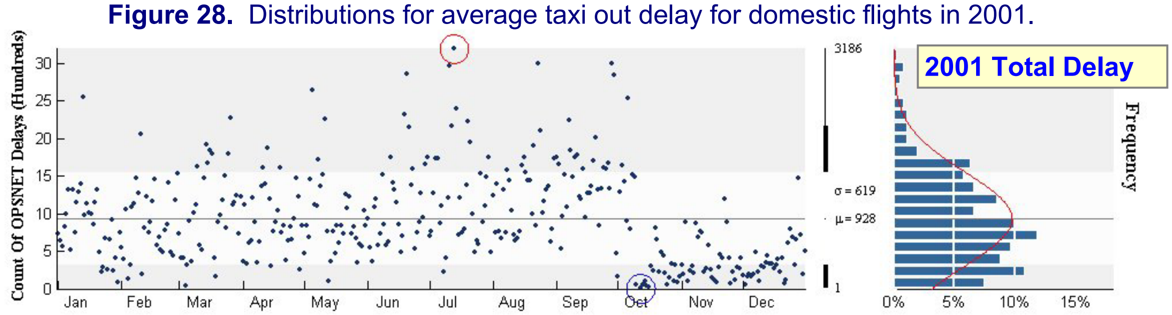

Figure 29. Total delayed operations in 2001.

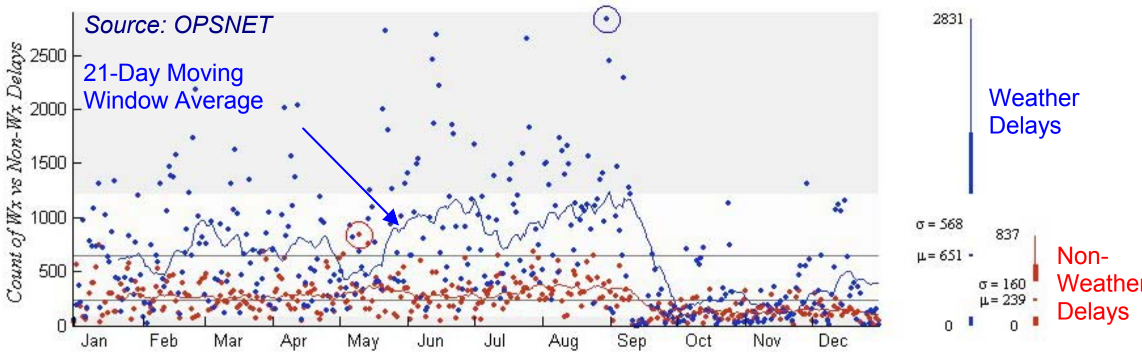

Figure 30. Weather Related vs. Non-Weather Related Delays in 2001.

Special Days in the NAS

Weather, holidays, special events, and rare events affect the NAS by causing increases or decreases in the volume of traffic. Yet, some of these occurrences have virtually no effect at all on NAS performance. These events also affect different parts of the country in different ways.

The following events categorize particular special days in the NAS:

- Severe Weather Days
- Holiday travel (day before a holiday vs. holiday vs. day after a holiday)
- Special event days
- Rare events

Convective weather season contains most of the severe weather days (e.g., pop-up thunderstorms), however, severe weather days (e.g., a hurricane) can also occur outside the convective weather season. Holiday travel occurs at different points in the year. Special events are usually yearly events other than holidays, such as the Super Bowl. Rare events include hijackings, major equipment outages, etc.

To address known special days, the ATCSCC has a list of Special Traffic Management Programs (STMPs) for special events for the year. There is also an online database of events occurring during the current month. STMPs tend to affect mostly smaller airports. We investigated if the following special events affected total NAS operations: Oshkosh Aviation Industry event, the Super Bowl, Winter Olympics, and the Sun-n-Fun Fly In.

The following rare event days have special air travel problems associated with them that are tested to identify if they are outside a normal distribution:

- Jan. 31, 2000 — Alaska Airlines MD-83 crash
- Sept. 14, 2000 — Hurricane Gordon
- Sept. 15, 2000 — Tropical Storm Helene
- Oct. 19, 2000 — ZLA radar equipment outage
- June 5, 2001 — Hurricane Allison
- Aug. 2, 2001 — Tropical Storm Barry
- Sept. 11, 2001 — Multiple Hijackings/Tragedy
- Sept. 14, 2001 — Tropical Storm Gabrielle
- Nov. 12, 2001 — Turbulence breaks a tail on an A-300 over Belle Harbour, NY

Figure 31 and **Figure 32** illustrate the daily OPSNET NAS operations for 2000-2001 and special days / events. The robust fit regression shown is less sensitive to outliers than the least squares method. The median and inter-quartile range was used to determine the measures of central tendency and dispersion, respectively, of the number of operations for the year. These descriptive statistics are more robust than the average or standard deviation. The green lines (top to bottom) represent the median plus the inter-quartile range, the median, and the median minus the inter-quartile range.

Severe Weather Days. Severe weather events that occurred in the time period of this study had little or no effect on overall NAS performance. For example, Hurricane Allison hit Texas hard but did not affect the overall operations of the NAS. This means the number of operations affected was too small to notice in the NAS aggregate statistics. A closer study of flights in and around Ft. Worth and Houston Centers reveals decreased operations. There was likely a plan in place when this event occurred and the affects of the storm were localized.

Winter storms are also known about in advance, but these storms occasionally hit an area harder than planned. Note that winter storms are characteristically different from summer storms in that winter storms are rarely convective. Also, winter storms tend to be at lower altitudes, and aircraft often navigate over such storms.

Holidays. For each observed year, the operations on holidays are low but increase on neighboring days. Passengers are usually at their destination on the actual holiday and thus the total number of operations falls on those days.

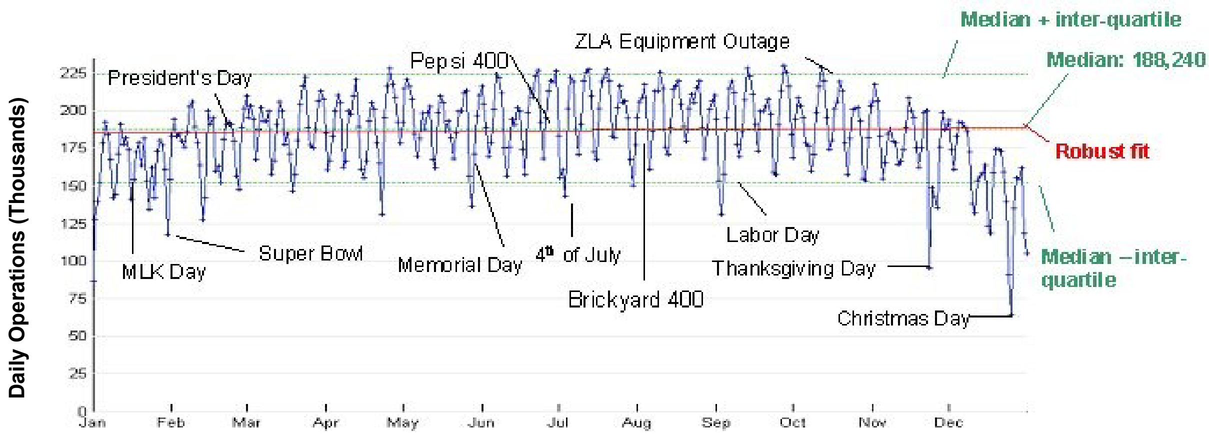

Figure 31. Daily NAS Operations and featured days for 2000.

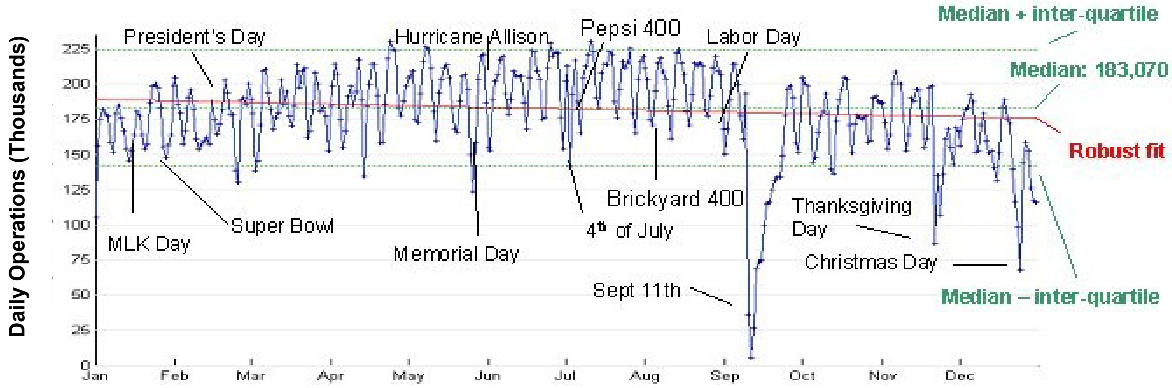

Figure 32. Daily NAS Operations and featured days for 2001.

ATCSCC specialists note that Thanksgiving travel is more predictable than Christmas travel. Thanksgiving always falls on a Thursday and travel tends to occur between the Wednesday before and the following Sunday. Not only is there an increase in travel the day after Thanksgiving, but there is also a decrease on the Saturday after Thanksgiving, followed by a significant increase on Sunday. Thanksgiving operations decrease by about 50% on the holiday and increase by about 50% the day after. Christmas sees a more gradual decrease in operations beginning 4 to 5 days before Christmas and an increase more than 100% the day after.

For holidays that typically fall on Mondays, such as Martin Luther King (MLK), Memorial Day, and Labor Day, the valleys in the graph occur on the days before the actual holiday, a Sunday. Sunday is a light travel day, in general, so it is fitting that the total number of operations is low. **Figure 31** and **Figure 32** show similar behavior between 2000 and 2001 operations around these holidays, i.e. peaks and valleys tend to occur at the same point in time. An increase in travel is evident the Thursday and Friday before the holiday, and the day after the holiday. Operations on these holidays fell well below the median.

Special Events. Special events like the Super Bowl, NASCAR, and Oshkosh have different effects on the NAS. Note that a STMP may preemptively avoid congestion for these events. Furthermore, these events affect the NAS locally around the location of these events, and thus, they may not affect (statistically) the entire NAS. Operations on Super Bowl Sunday fall well below the median while Pepsi 400 Saturday sees almost average operations. The Sunday of the Brickyard 400 finds slightly above average operations. The Oshkosh Event takes place over a week; the number of operations appears to follow the usual trend of NAS volume for that week. For these events, it must be determined whether or not the actual events are the reason for the slow traffic or because it is a Sunday or Saturday, which normally sees lower operations.

Rare Events. Rare events have different effects on total operations. Some are planned for, such as hurricanes and tropical storms (see Severe Weather Days section). Other rare events are unexpected, such as equipment failures and hijackings. Within the time period of this study, an equipment outage, the result of a computer software upgrade, occurred in Los Angeles Center on October 19, 2000. Even with two outages on that day, the outages had no statistically significant effect on total NAS operations. There was backup equipment being used during these outages also, so this could contribute to the minimal impact on operations.

The events of Sept. 11, 2001 had an overwhelming effect on operations that day and several days after[3]. The hijackings took place in the morning (East Coast Time), which is the beginning of daily operations throughout the NAS. A NAS-wide GS was issued along with en route flights being forced to land. Thousands of flights never got underway.

Analysis of Special Days in the NAS

In order to determine which days had a significant impact on operations, special days and events that fell outside of one inter-quartile range were considered to have noticeably impacted operations. Some special events such as the Super Bowl make a noticeable impact on NAS operations, while other special events such as racing events and Oshkosh, have little or no effect on NAS operations As stated earlier, MLK Day, Labor Day, and Memorial Day behave similarly and have a noticeable influence on the NAS. These holidays take place on Mondays and weekend travelers tend to extend their trips one day and return on the holiday. Therefore, operations increase on the actual holidays and a few days before the holidays. President's Day has almost no impact on operations. Thanksgiving and Christmas operations also behave similarly in that they greatly impact the NAS. The days before see just above average operations. Operations considerably decrease on the actual holiday and significantly increase the days after. Rare events specific to small regions of the country are localized by TFM procedures and thus do not greatly affect the NAS. Examples are hurricanes and equipment outages. Obviously, a rare event such as September 11th drastically affected operations.

Table 3 summarizes all of the above findings. The data is classified as follows:

- **High:** Data falls 1σ or more from the median μ.
- **Medium:** Data between 0.5 σ and 1 σ from μ
- **Low:** Data falls within 0.5 σ from the median μ

A "High" score means operations significantly increased in a positive or negative direction and a "Low" score means operations barely changed. A score of "NO Effect" means there was no apparent effect on operations. Recall that although the actual day may have no effect, the days surrounding an event may be affected.

Table 3. Summary of Special Days.

Day	Overall Effect on NAS
MLK Holiday	Medium
Super Bowl	**High**
President's Day	NO Effect
Memorial Day	Medium
Hurricane Allison	NO Effect
4th of July	**High**
Pepsi 400	NO Efftect
Oshkosh	NO Effect
Labor Day	Low
Sept. 11th	**High**
ZLA Outage	NO Effect
Thanksgiving	**High**
Christmas	**High**

Conclusions

In this paper, NAS data sources were aggregated and analyzed for notable historical trends. We gave a characterization of NAS states, controls, and performance metrics. Data, statistics and histograms for a selection of these elements of the NAS revealed some illuminating facts about NAS performance:

- Weekday versus weekend traffic trends
- Effects of the convective weather season
- Frequency and location of GDPs and GSs
- Miles-in-trail restriction density over the NAS
- Taxi-out versus taxi-in delay discrepancies
- Timing of flight cancellation notices

We also analyzed special and rare days in the NAS. Data and statistics were shown that illustrate expected effects of a drastic event such as the September 11th tragedy. Of all holidays and special events examined, Independence Day, the Super Bowl, Thanksgiving and Christmas greatly impact the NAS. Operations are found to considerably decrease on holidays and increase on neighboring days. Rare events such as hurricanes and equipment outages typically impact only small regions of the country; hence, they do not greatly affect NAS operations. Further studies are required to fully understand the ramifications of these events.

Acknowledgments

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