A New Approach to Measuring the Effect of Weather on NAS Performance

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Background
The performance of the National Airspace System (NAS) is dependent on a number of operational and environmental factors, including scheduling decisions on the part of airlines, the availability of airport and traffic management facilities and equipment, and the timing, location and severity of adverse weather conditions. Of these, adverse weather is a dominant factor influencing performance. According to the FAA’s Operations Network (OPSNET) data, weather is the cause of approximately 70% of flight delays in the NAS.

All NAS participants, including the FAA, airports and airlines would like to operate in the NAS during poor weather, or Instrument Meteorological Conditions (IMC), at performance levels achieved during good weather, or Visual Meteorological Conditions (VMC). The extent to which NAS performance is reduced during IMC constitutes the performance gap between IMC and VMC.

Air traffic operations, particularly during the approach and landing phases of flight, are particularly impacted by IMC. When visual separation between aircraft cannot be maintained, larger separation standards apply. The resulting larger spacing between aircraft leads to fewer operations in a given time period. Existing, as well as emerging, technologies and procedures (e.g., PRM, SOIA, ADS-B, CDTI) and airport construction projects (e.g., new runways) may help close the performance gap between IMC and VMC.

In order to help evaluate the impact of NAS improvements, with a focus on achieving VMC-like performance in IMC, the FAA sought to develop an approach to directly measure the IMC/VMC performance gap.

This analysis describes the development of a methodology for evaluating whether changes to the NAS can be shown to help achieve VMC-like operations under IMC. This study is intended to provide the FAA with an approach that could be used to measure the effect of weather on NAS performance with a focus on measuring differences in performance of flights occurring in IMC and VMC to evaluate how weather conditions impact NAS performance.

The study investigates performance at Hartsfield-Jackson Atlanta International Airport (ATL) before and after the introduction of a new runway in 2006.

Analysis Approach
A regression analysis was conducted to determine the relationship between scheduled demand and actual throughput at the airport, identify the throughput saturation level (the average throughput achieved by the airport at the highest levels of scheduled operations), and understand how this relationship has changed as a result of specific NAS enhancements, in this case, the introduction of a new runway at ATL.

As illustrated in Figure 1, the regression line estimates the relationship between scheduled operations and achieved throughput at the airport. For lower values of scheduled operations, as the number of scheduled operations and achieved operations increase, the slope of the regression line is typically near 1, indicating that the airport has the capacity to serve each additional aircraft scheduled to arrive or depart. As the number of scheduled operations increase, a point is reached at which the slope of the regression line flattens out to approximately zero; that is, throughput no longer increases despite the increase in scheduled demand. The point at which the slope of the line changes from one to zero is the saturation point, and the corresponding throughput is the saturation throughput level.

The regression analysis was conducted using a piece-wise linear model fit to observed data using the least-squares technique. All regressions reported here are significant at an α=.05 level.

While this report is focused on ATL, it is important to note that most actual airport data follow the pattern
illustrated in Figure 1. However, other patterns have been observed. For example, some airports do not have enough scheduled operations to reach a saturation point at which the slope levels off. In these cases, a single line with slope approximately equal to one gives the best fit. However, for most airports the piece-wise linear pattern shown in Figure 1 provides a statistically significant fit to observed data.

Using the saturation throughput estimated by these regressions, IMC and VMC throughputs can be compared to determine the gap in performance. Figure 2 is a notional depiction of the difference in throughputs between VMC and IMC, illustrating the IMC-VMC gap. As IMC and VMC performance become more similar, the gap in performance closes. The analysis described in this report was designed to isolate this gap and detect whether or not the introduction of capacity enhancing technologies, procedures, or infrastructure helped to narrow this gap.

Numerically, the performance gap is equal to the difference between IMC and VMC throughput. For example, if the IMC throughput is 45 arrivals per hour and VMC throughput is 50, then IMC performance is 90% of VMC, and thus the gap is 10% (100% - 90%). If IMC performance is equal to VMC performance, the gap is zero.

Data

The FAA Aviation System Performance Metrics (ASPM) database includes performance data on operations at 77 airports, including the OEP 35 airports [1]. ASPM combines data from several data sources, including Operations Network (OPSNET), Airline Service Quality Performance (ASQP), Enhanced Traffic Management System (ETMS), and Aircraft Communications Addressing and Reporting System (ACARS) in a single database that can be queried for specific performance metric data. ASPM combines environmental data, such as weather conditions, with performance data, such as arrival and departure counts and delays. The database includes extensive data categorization, including airport-specific identification of Instrument and Visual approach conditions and a measure of weather severity.

For the purpose of this study, hourly ASPM data were collected for Government Fiscal Year (FY) 2005 to FY 2007 to measure performance in IMC and VMC at the hourly observation level.

Weather Conditions Definitions

The analysis described in this report is based on distinguishing between types of weather conditions. The ASPM database categorizes meteorological conditions as either Visual Approach (VA) or Instrument Approach (IA) conditions, based on airport-specific limits of ceiling and visibility. Under VA conditions, the airport is considered to be using visual approaches, while instrument approaches are used during time periods categorized as IA. In this analysis, VA and IA, as reported in ASPM, are used as airport-specific proxies of VMC and IMC, respectively. IA conditions at ATL are defined by visibility less than 7 miles or ceiling less than 3600 feet, and VA conditions at ATL are defined by visibility greater than or equal to 7 miles or ceiling greater than or equal to 3600 feet. IA and VA categorizations are used in order to account for airport-specific operating characteristics.
Case Study: Hartsfield-Jackson Atlanta International (ATL)

Overview
On May 27, 2006 a fifth runway was commissioned at ATL which, according to the OEP v7, was expected to increase capacity approximately 33% [2]. This section evaluates the performance of aircraft arriving and departing ATL in VA and IA conditions before and after this runway was commissioned to understand how the addition of a new runway impacted performance. Results are presented for the airport for FY05 (as a measure of performance pre-runway) and FY07 (post-runway).

It is important to note, however, that not all of the performance changes observed at the airport over this timeframe can be attributed solely to the new runway; other factors may affect the airport’s performance and the results of the analysis.

Throughput Regression Analysis
The regression analysis of performance at ATL evaluates changes in throughput in both absolute terms and in terms of the gap in performance in IA and VA conditions. The hypothesis for the regression analysis is that the introduction of an additional runway should increase both arrival and departure throughputs. At the same time, the expectation is that the gap in performance between Instrument and Visual conditions should narrow due to the introduction of the new runway.

Arrival Throughput
Figure 3 through Figure 6 show the results of the regression analyses conducted for arrivals at ATL. Each figure provides a scatterplot of the scheduled arrivals (measured on the x-axis) versus actual arrivals (measured on the y-axis). The scheduled arrivals measure demand while the actual arrivals measure throughput. The regression line represents the degree to which throughput keeps up with demand. In each graph, the regression line tends to flatten (slope approaches zero) at the point at which the airport has reached its saturation level. This transition point defines the saturation throughput for the airport in the specific weather conditions (IA or VA).

As shown in Figure 3, throughput in VA for arrivals in FY05 leveled off at approximately 89 arrivals per hour. Figure 4 shows that VA throughput for arrivals in FY07 leveled off at approximately 101 per hour. This represents a 14% increase in the VA saturation arrival throughput rate versus FY05.

Figure 5 shows that IA arrival throughput leveled off at approximately 74 per hour. As shown in Figure 6, IA arrival throughput leveled off at approximately 90 per hour. This represents a 21% increase in the IA arrival throughput versus FY05. Note that there is substantially greater variance of actual throughput at all levels of demand in IA than in VA (compare Figure 5 to Figure 3). This is likely to be due to two factors; 1) there is more variability in IA conditions (i.e., not all periods of IA are equivalently severe), and 2) there is a higher likelihood of operational disruptions in IA.
The performance gap for ATL arrival throughput can be calculated based on the IA and VA throughputs estimated above. For FY05, the performance gap is 17% (=100% – (74/89)), and for FY07, the gap is 11%. This 6% improvement (decrease) in the performance gap represents a narrowing of the gap by about one-third.

The results for arrival throughput, summarized in Table 1, suggest that installation of a new runway at ATL resulted in increased throughput in both VA and IA, and helped close the performance gap from IMC throughput that was 83% of VMC in FY05 to 89% in FY07.

**Departure Throughput**

Figure 7 through Figure 10 show the regression analyses conducted for departure throughput at ATL. Figure 7 shows that VA departure throughput in FY05 leveled off at approximately 81 per hour. As shown in Figure 8, VA departure throughput in FY07 leveled off at approximately 86 per hour. This represents a 6% increase in the VA departure throughput from FY05.

Figure 9 shows that IA departure throughput in FY05 leveled off at approximately 80 per hour. As shown in Figure 10, IA departure throughput leveled off in FY07 at approximately 83 per hour. This represents a 4% increase in the departure rate from FY05.

The performance gap for ATL departure throughput can be calculated based on the IA and VA throughputs estimated above. For FY05, the performance gap is 1% (=100% – (80/81)), and for FY07, the gap is 3%. This small difference is well within the statistical variance of the observed data and should not be interpreted as an indication of reduced departure throughput performance. Instead, these results reflect the difficulty in measuring improvements to a small performance gap (1%) in the presence of substantial observational variance.

The results for departure throughput, summarized in Table 2, suggest that while the introduction of the new runway had a positive impact on departure throughput, it is less than the impact on arrival throughput.

### Table 1. ATL: Arrival Saturation Throughput Summary

<table>
<thead>
<tr>
<th>ATL</th>
<th>FY05</th>
<th>FY07</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td>74</td>
<td>90</td>
<td>+16</td>
</tr>
<tr>
<td>VA</td>
<td>89</td>
<td>101</td>
<td>+12</td>
</tr>
<tr>
<td>Performance Gap</td>
<td>17%</td>
<td>11%</td>
<td>-6%</td>
</tr>
</tbody>
</table>

### Table 2. ATL: Saturation Throughput Summary for Departure Operations

<table>
<thead>
<tr>
<th>ATL</th>
<th>FY05</th>
<th>FY07</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td>80</td>
<td>83</td>
<td>+3</td>
</tr>
<tr>
<td>VA</td>
<td>81</td>
<td>86</td>
<td>+5</td>
</tr>
<tr>
<td>Performance Gap</td>
<td>1%</td>
<td>3%</td>
<td>+2%</td>
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Total Throughput
An additional analysis was conducted to estimate the saturation throughputs for Total Operations (Arrivals + Departures). As with saturation throughput for arrivals and departures, the regression analysis of total operations saturation throughput measures the relationship between scheduled operations and actual operations.

The results for total throughput, summarized in Table 3, show that total airport throughput increased and the overall performance gap decreased by 3%.

Supplemental Regression Analysis: Evaluation of PRM at ATL
In April 2007, a Precision Runway Monitor (PRM) landing system was installed at ATL. “The new precision runway monitoring system…at Atlanta-Hartsfield is going to allow up to 23 additional aircraft an hour to land at the airport” [3]. A regression analysis similar to that described in Sec. 0 was conducted with IA throughput data for the seven months
prior to installation of PRM (October 2006 through April 2007) and the five months after installation (May 2007 through September 2007) to determine how PRM has affected IA throughput at ATL. A similar analysis was conducted on a control period (October through April and May through September) for FY03-FY05 to ensure that the seasonal differences in performance were accounted for in the analysis. A summary of the results are shown in Table 4, with the post-PRM results highlighted.

Comparing the results for All Months in FY07 to FY03-FY05 in Table 4, there is an increase in estimated IA arrival throughput from 73 to 90 flights per hour. However, isolating the pre- and post-PRM months in FY07, the estimated IA throughput was higher after the PRM was installed than before (92 vs. 88), suggesting that the PRM had a measurable impact on increasing arrival throughput during IA conditions at ATL.

**Summary of Results**

The findings of this analysis support the contention that the new runway at ATL has improved both overall throughput at the airport and closed the performance gap between IA and VA operations.

Saturation throughput at ATL increased in both IA and VA conditions after the new runway was placed into service. The increase in arrival saturation throughput was greater in IA than VA, so the gap in arrival performance narrowed. On the departure side, however, the increase in saturation throughput was greater in VA than IA, so the gap for departure performance widened slightly. Overall, as shown in Table 3, for combined arrival and departure operations, the new ATL runway helped close the performance gap.

**Conclusion**

Identifying a methodology for measuring how well airport improvements help to achieve VMC-like operations under IMC is just a first step. For example, the saturation throughput methodology developed in this study can be applied to multiple airport or airspace improvement scenarios to compare the effectiveness of an enhancement across airports. Other potential applications for this methodology include analyzing the NAS-wide impacts of technology, procedure or infrastructure improvements; understanding seasonal variations in performance at one or multiple airports; and prospectively evaluating the potential benefits of future planned NAS enhancements.

The performance gap methodology described in this paper was used to evaluate an implemented airport-specific operational change. Application of this methodology to create forecasts of the impact of proposed NAS enhancements based on findings from similar enhancements already implemented can help to prioritize among investment alternatives. Thus, the approach described here can also assist in the evaluation and prioritization of NextGen investments based on their likely impact to airport-specific or NAS-wide operational performance.

**References**

[1] aspm.faa.gov/aspm


[3] Speech given by Transportation Secretary Mary Peters in January 2007, before the Aero-Club of Washington

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### Table 4. ATL: IA Saturation Throughput with and without PRM

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Saturation Throughput (Arrivals per hour)</th>
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<tbody>
<tr>
<td></td>
<td>FY03-FY05 IA</td>
</tr>
<tr>
<td>All Months</td>
<td>73</td>
</tr>
<tr>
<td>(October to April)</td>
<td>72</td>
</tr>
<tr>
<td>(May to September)</td>
<td>74</td>
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**About the Author**

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