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# Performance Metrics in the National Airspace System: Relationship between Weather, Traffic and Delay

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# Outline

- **Motivation**
- **Objective**
- **Weather Impacted Traffic Index**
- **NAS Delay Prediction Model**
- **Published NAS Delay Data and Traffic Demand Data**
- **Model Validation**
- **Summary**



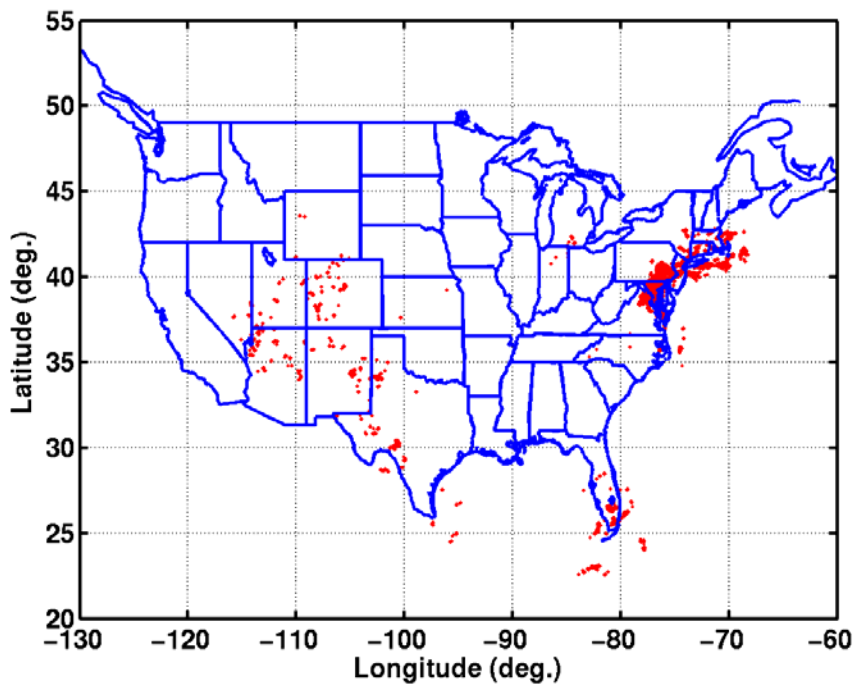
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# Motivation

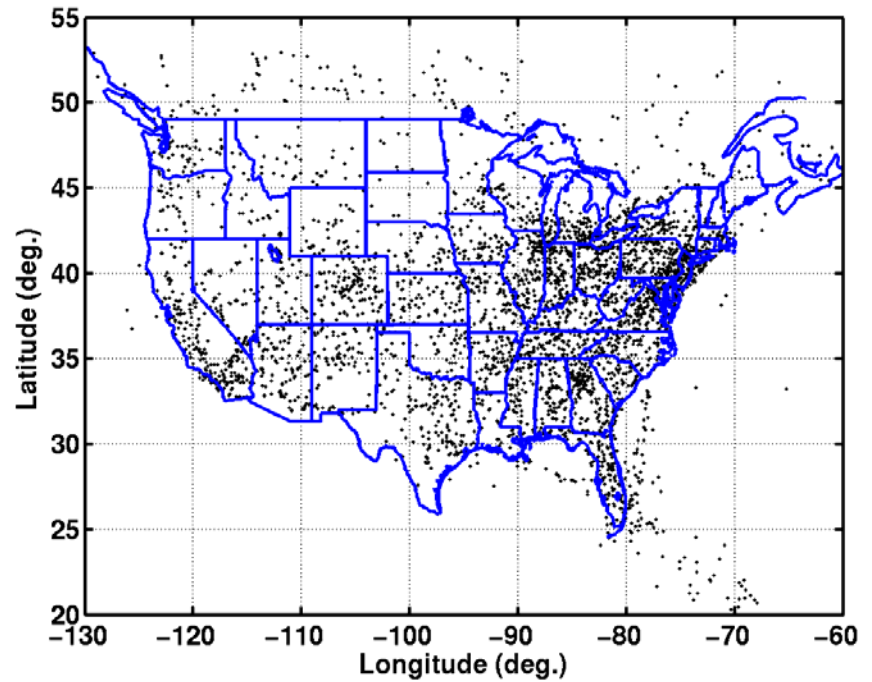
- **Traffic Flow Management initiatives in response to surface & enroute weather are the major cause of NAS delays.**
- **A method is needed to determine the performance of NAS relative to the weather conditions.**



# Weather and Traffic (28 September 2004)



**Severe weather**



**Aircraft positions**





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# Objectives

- **Develop a NAS delay estimation model based on expected traffic, and surface and enroute weather.**
- **Validate the delay estimation model by comparisons against actual observed delays.**
- **Use the NAS delay estimation model to determine performance relative to weather conditions.**



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## Weather Impacted Traffic Index

- **A method is needed for quantifying the effect of surface and enroute weather on traffic for NAS delay modeling.**
- **A measure defined as the Weather Impacted Traffic Index (WITI) has been developed for this purpose.**
- **A functional relationship between the WITI measure and observed NAS delays is established for building a NAS delay estimation model.**



## Weather Impacted Traffic Index

$$WITI(k) = \sum_{1 \leq j \leq m} \sum_{1 \leq i \leq n} T_{i,j}(k) W_{i,j}(k)$$

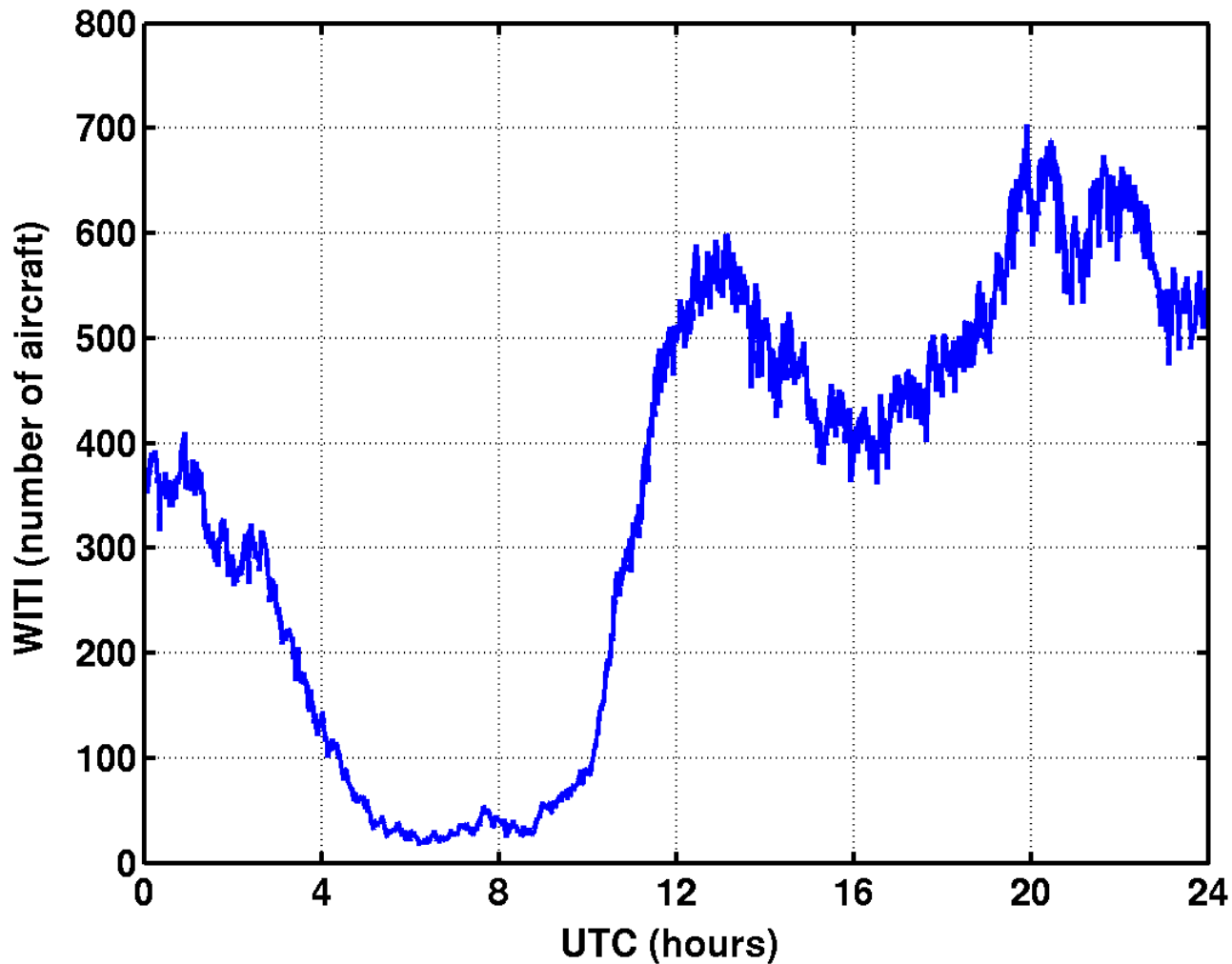
$W_{i,j} = 1$  at (i, j) location for weather level  $> 2$

$T_{i,j}$  = Traffic counts at (i, j) location

**Grid: 1837 Rows X 3661 Columns; Size: 1 mile x 1 mile**



# Computed WITI for 28 September 2004

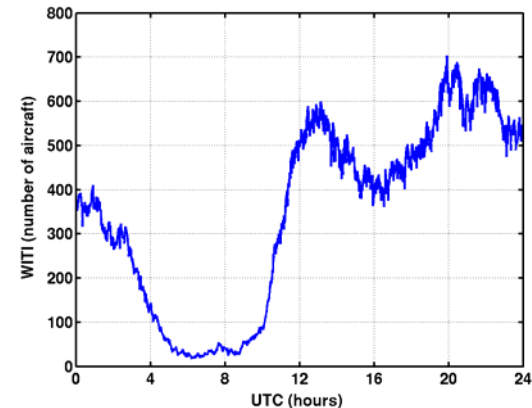






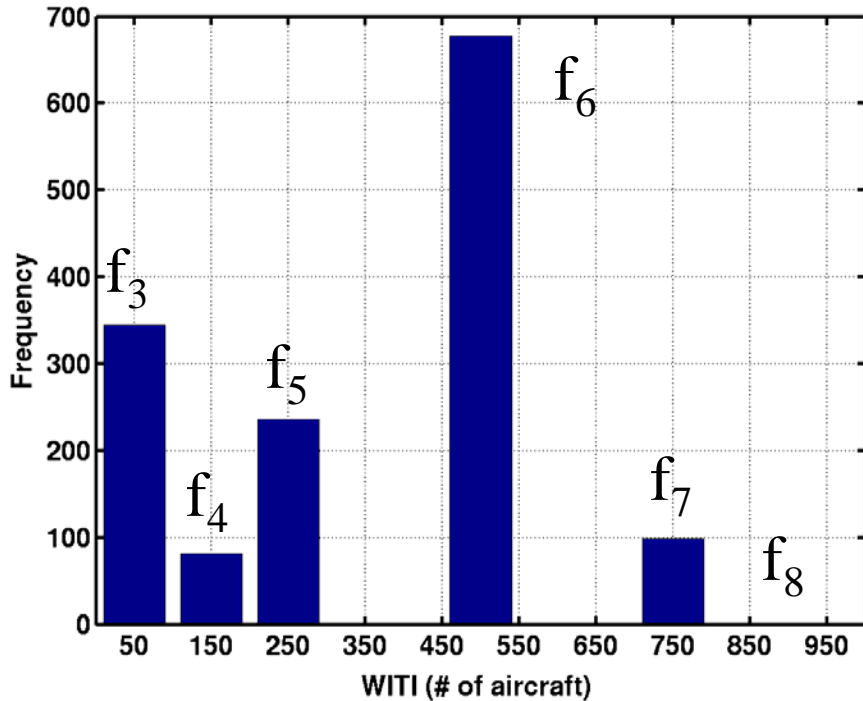
# Weather Features

- Measures of WITI time history, and surface wind speed and visibility.
- 16 such measures developed
  - Average WITI:  $f_1$
  - Standard deviation:  $f_2$
  - Values of six selected histogram bins:  $f_3, \dots, f_8$
  - Values of six selected time bins:  $f_9, \dots, f_{14}$
  - Number of major airports with wind speed  $> 5$  knots:  $f_{15}$
  - Number of major airports with visibility  $< 6$  miles:  $f_{16}$

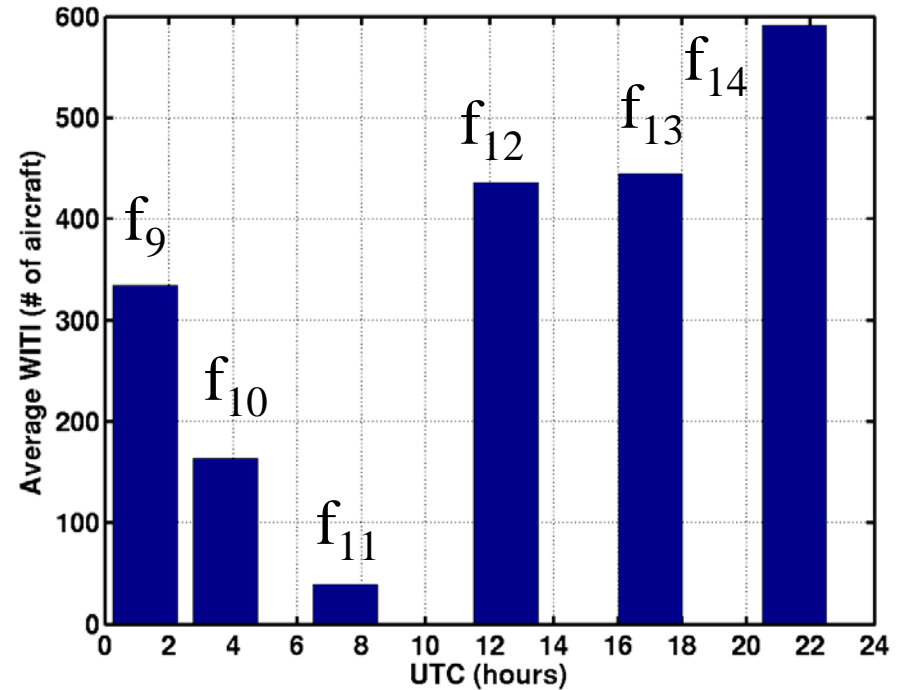




# WITI Features (28 Sept. 2004)



**Histogram features**



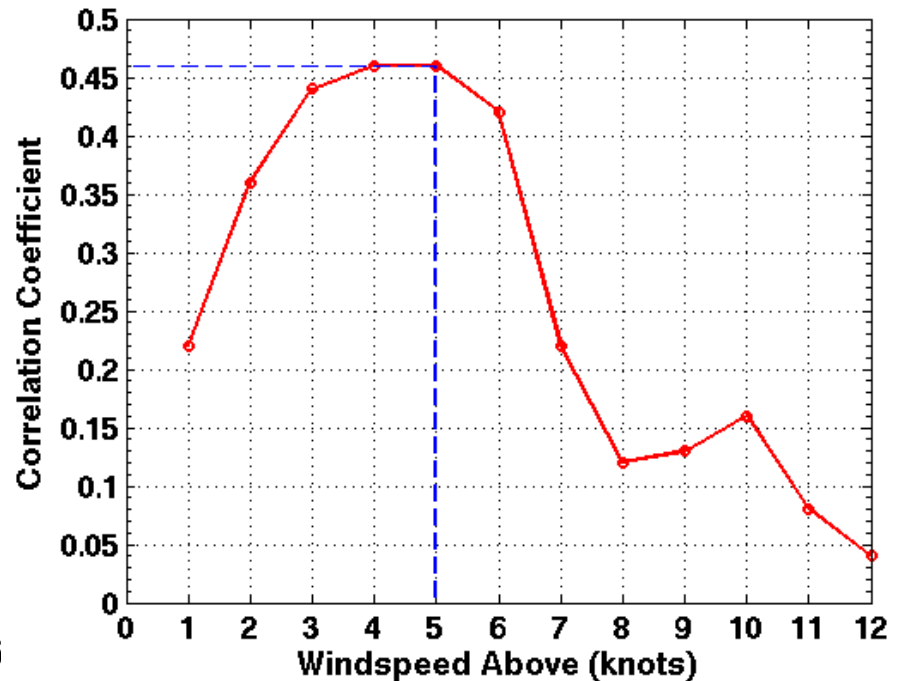
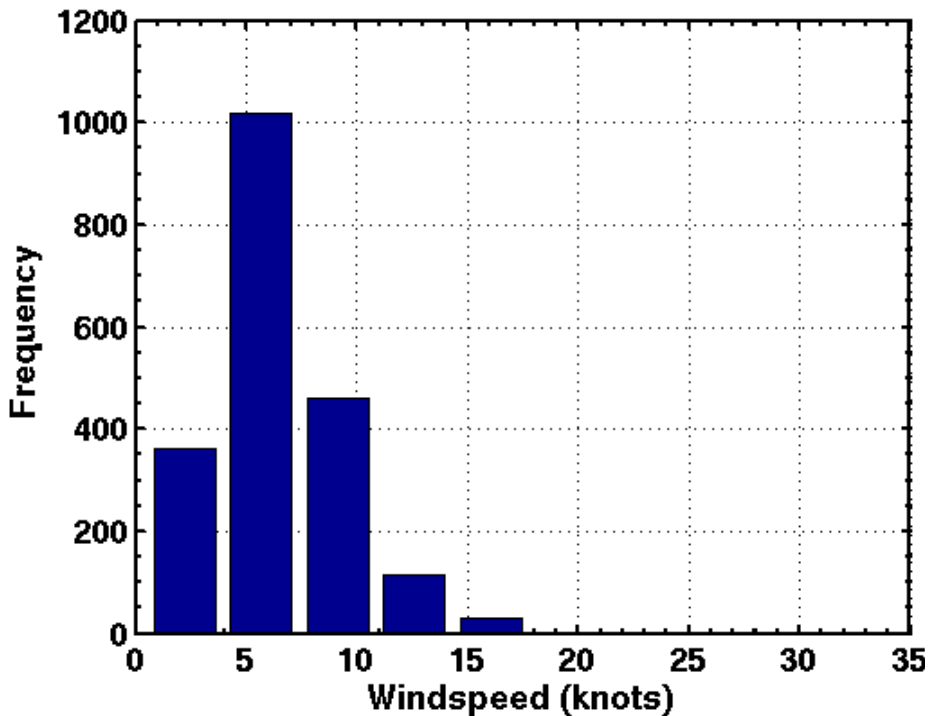
**Average in time bins**

**Statistical features:**  $f_1$  mean = 348 aircraft  
 $f_2$  standard deviation = 211 aircraft





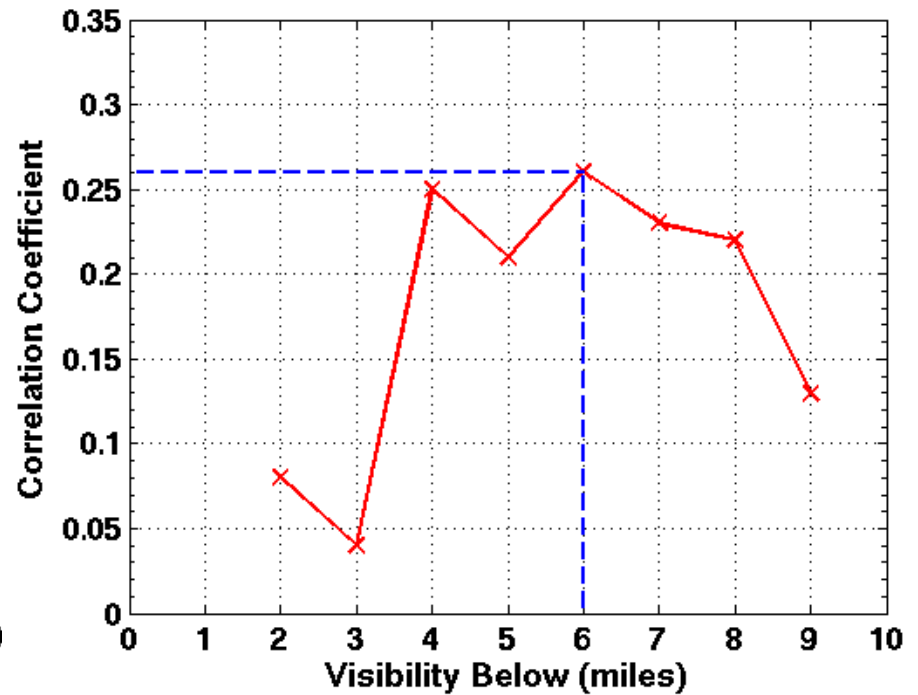
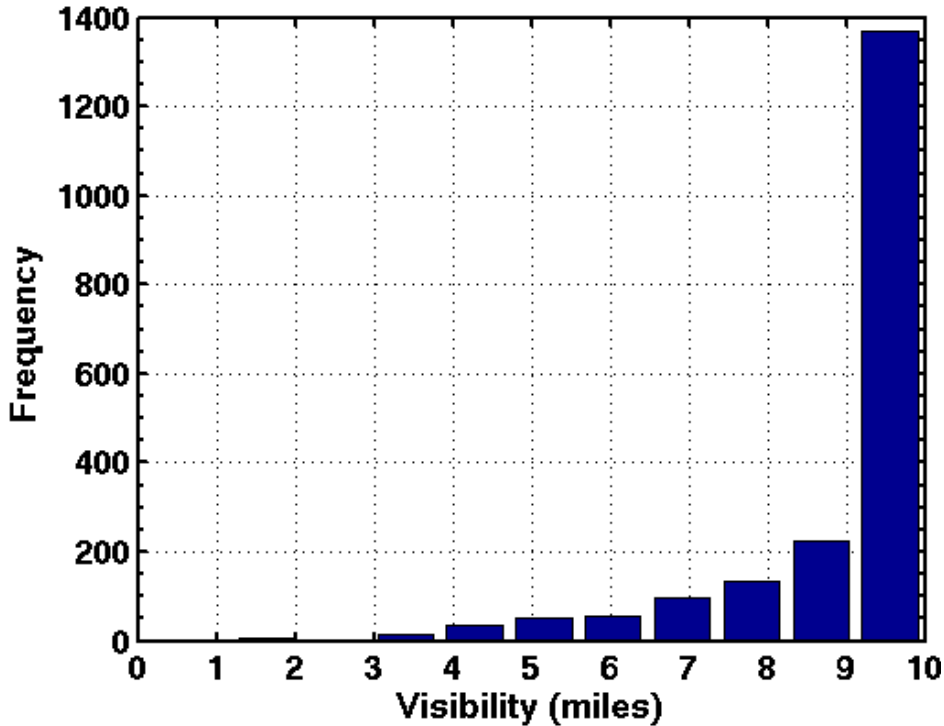
# Surface Features: Wind speed



**1989 samples: 51 airports on 39 days.  
Wind speed > 5 knots.**



# Surface Features: Visibility



**1989 samples: 51 airports on 39 days.  
Visibility < 6 miles.**





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## Published NAS Delay Data

- **Available on FAA's Operations Network (OPSNET) web site: <http://www.apo.data.faa.gov>**
- **Category: Departure, Arrival, Enroute, Traffic Flow Management.**
- **Class: Air Carrier, Air Taxi, General Aviation, Military.**
- **Cause: Weather, Volume, Equipment, Runway.**
- **Time Delays: Total and average delays in minutes (Only delays > 15 minutes trigger an entry)**



# Summary of Data Used

<b>Data Type</b>	<b>Source</b>
<b>Aircraft Positions</b>	<b>ETMS</b>
<b>NOWRAD</b>	<b>ETMS</b>
<b>Wind &amp; Visibility</b>	<b>NCDC</b>
<b>NAS Delay</b>	<b>OPSNET</b>
<b>Aircraft Handled</b>	<b>OPSNET</b>

## Initial Set

- **42 days for building reference days.**
- **39 days used for building the model.**
- **26 days used for validating the model.**

## Current Set

- **120 days (June 05 -Sep 05)**





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## Selection of Reference Days

- **Reference day is defined as a day with little or no severe weather, normal traffic demand and low observed NAS delays.**
- **WITI concept requires traffic demand independent of weather because actual traffic is rerouted to avoid severe weather.**
- **Reference days computed for each day of the week based on analysis of 42 days of traffic data.**
- **Demand on a given day modeled as demand on a reference day.**



# Selected Reference Days

Day	Date	Delay	Max. Delay	# Ac.
Mon.	5/3/2004	53,212	156,967	128,748
Tue.	4/27/2004	12,859	123,709	136,390
Wed.	5/5/2004	20,167	170,789	139,921
Thu.	4/22/2004	15,966	186,313	143,399
Fri.	4/23/2004	39,991	175,187	137,874
Sat.	4/17/2004	5,172	59,775	107,423
Sun.	5/16/2004	20,982	105,525	116,443







# NAS Delay Estimation

$$\begin{array}{c} \text{Number of Days} \\ \left[ \begin{array}{cccc} f_{1,1} & f_{1,2} & \cdots & f_{1,r} \\ f_{2,1} & f_{2,2} & \cdots & f_{2,r} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ \vdots & & & \vdots \\ f_{s,1} & f_{s,2} & \cdots & f_{s,r} \end{array} \right] \begin{array}{c} \\ \\ \\ \\ \\ \\ \\ \\ \\ \left[ \begin{array}{c} w_1 \\ w_2 \\ \vdots \\ w_r \end{array} \right] \end{array} = \begin{array}{c} \\ \\ \\ \\ \\ \\ \\ \\ \\ \left[ \begin{array}{c} d_1 \\ d_2 \\ \vdots \\ \vdots \\ \vdots \\ d_s \end{array} \right] \end{array}$$

$$\hat{d}_k = \left[ f_{k,1} \quad f_{k,2} \quad \cdots \quad f_{k,r} \right] w$$





# NAS Delay Estimation Results

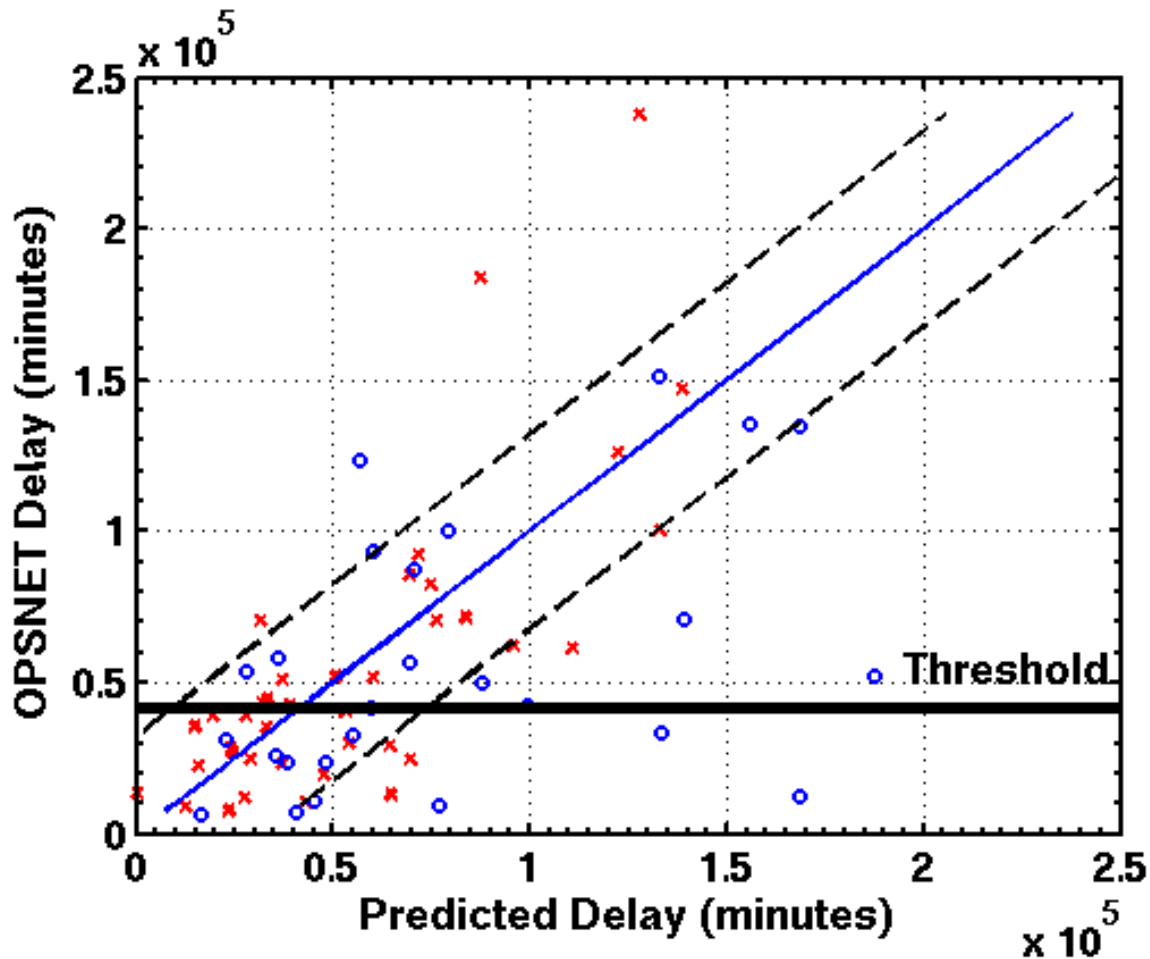
#	Features	Corr. Coeff.
1	$f_1$	0.43
2	$f_1, f_{15}, f_{16}$	0.54
3	$f_1, f_2$	0.44
4	$f_1, f_2, f_{15}, f_{16}$	0.54
5	$f_9 - f_{14}$	0.61
6	$f_9 - f_{14}, f_{15}, f_{16}$	0.68
7	$f_3 - f_8$	0.50
8	$f_3 - f_8, f_{15}, f_{16}$	0.59
9	$f_1, f_3 - f_8$	0.66
10	$f_1, f_3 - f_8, f_{15}, f_{16}$	0.75

- **Correlation with 6 temporal features and 2 surface features 0.68.**
- **Best correlation with mean WITI, 6 histogram features and 2 surface features 0.75**





# NAS Delay Validation Results



x – Model 39 days

o -Validation 26 days

- 85% within error bounds for 39 days of data used for building the model.
- 73% within error bounds for 26 days of model validation data.



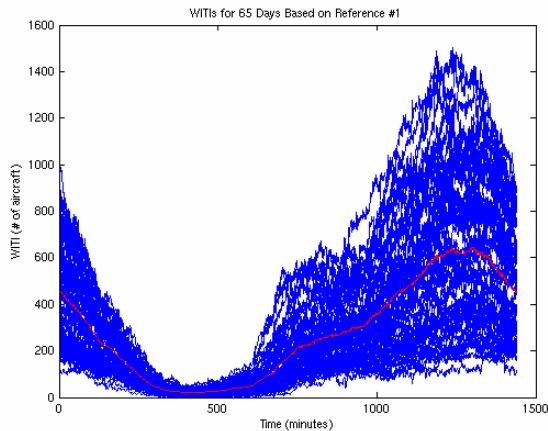
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## Current research directions

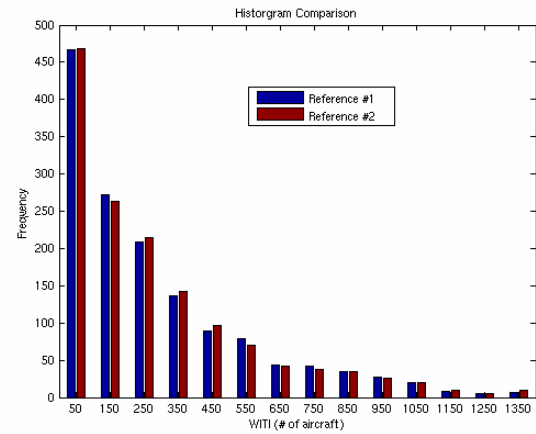
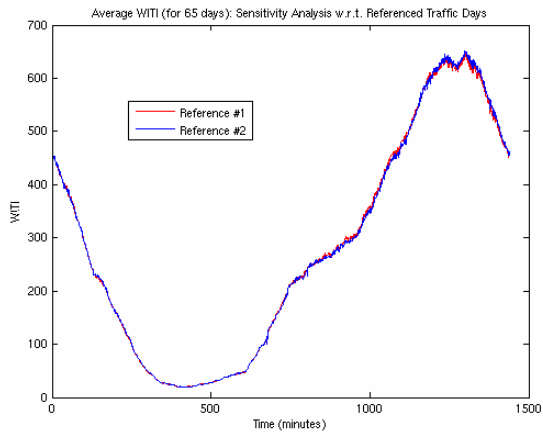
- **Influence of reference days on delay estimation**
- **Effect of multiple regression models**
- **Effect of Cancellations**
- **Towards an envelope of operations**
- **Center Level Operations**



# Sensitivity of WITI to Normal Day

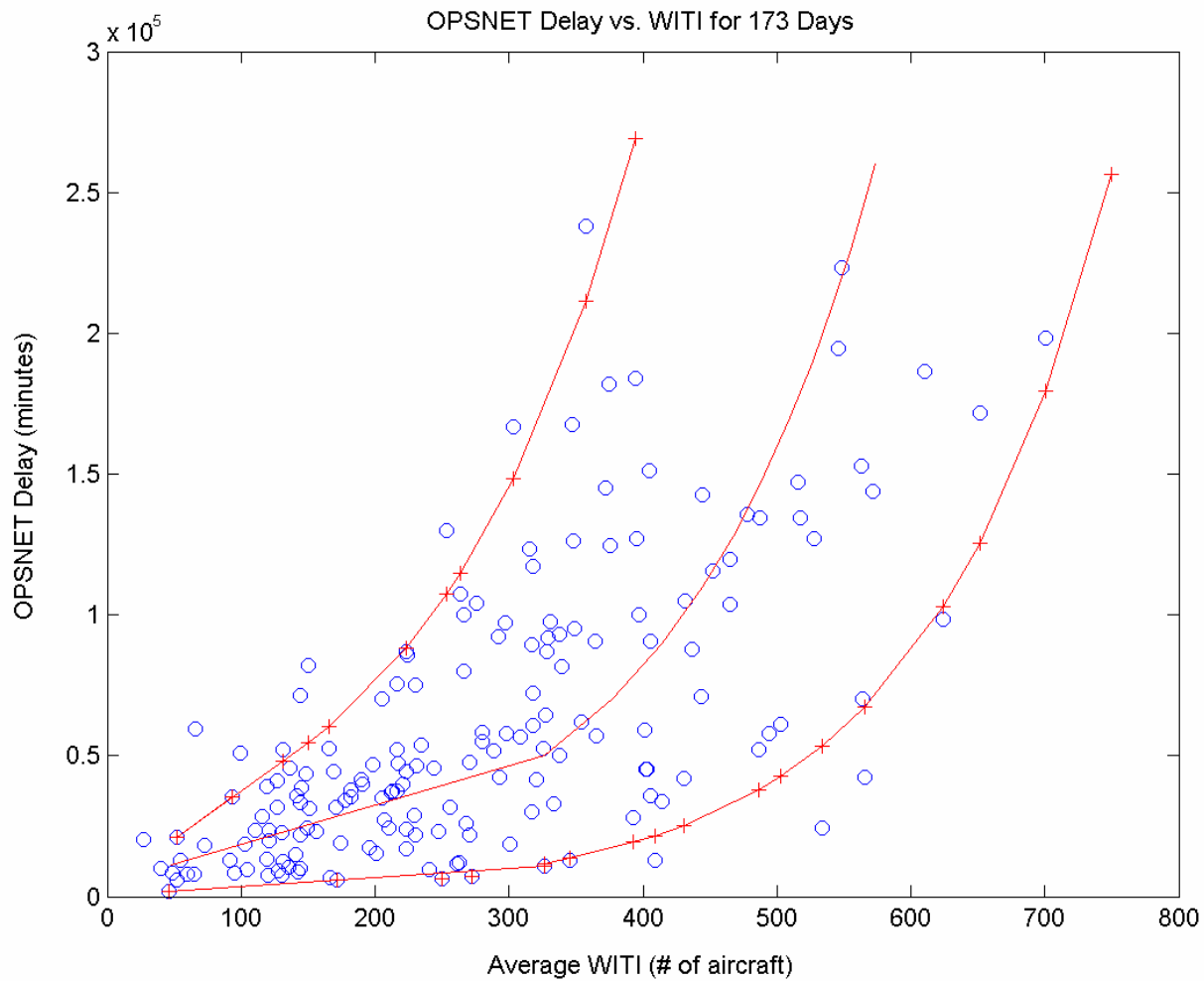


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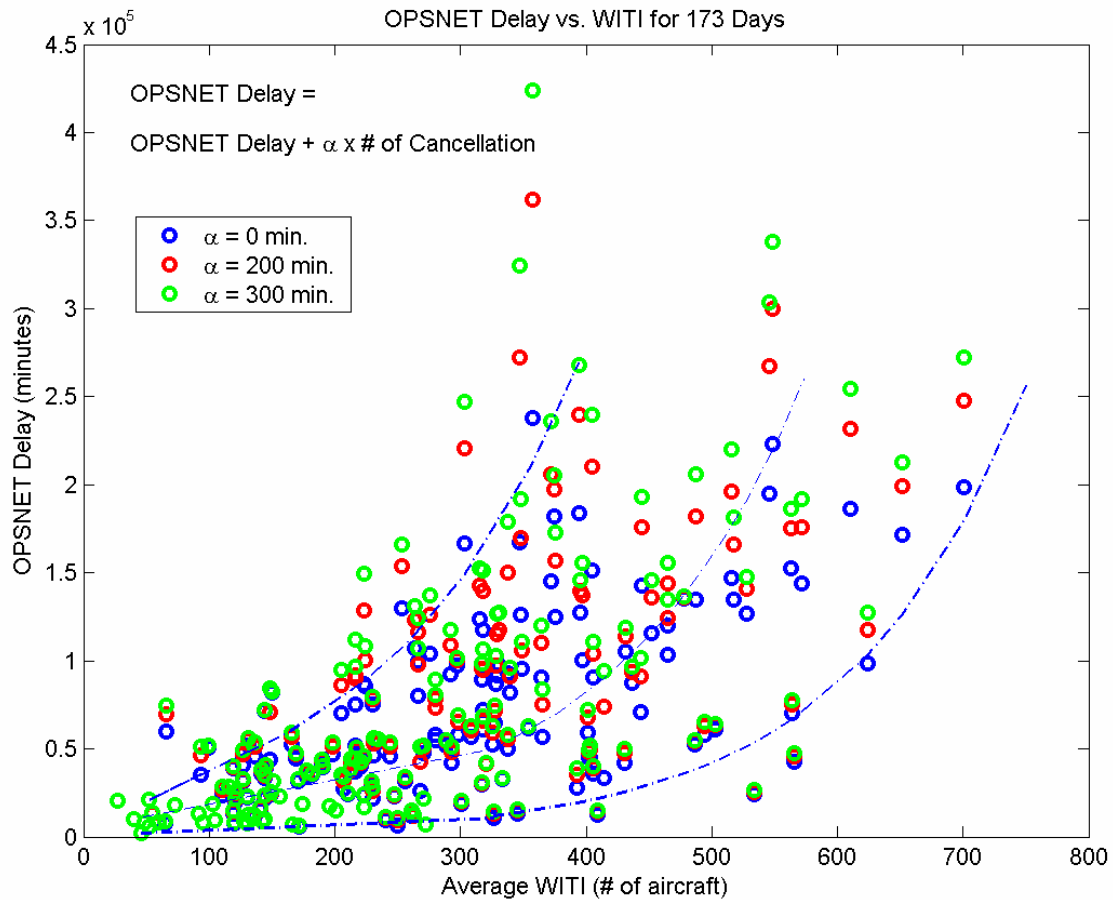


# Performance Envelope





# Effect of Cancellations





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## Summary

- **NAS delay prediction model built and validated using Weather Impacted Traffic Index (WITI) and surface weather features, OPSNET delay data.**
- **Best correlation with mean WITI, 6 histogram features and 2 surface features.**
- **New model shows an improvement over the basic model.**
- **Described the potential of the method for assessing NAS delay performance relative to weather conditions.**