Delay Metrics
Why are Delays Increasing?

Presented to NEXTOR Performance Workshp

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Date: 6 September 2007

What is causing Delay Increases?

NY Traffic (JFK?)
Weather

NAS Performance Measures (Delay FY07 vs. FY06)

NAS On-Time

- Down ~2%

DOT On-Time Arrival

- Down ~4.0%

OPSNET Delay

- Up ~2.5%
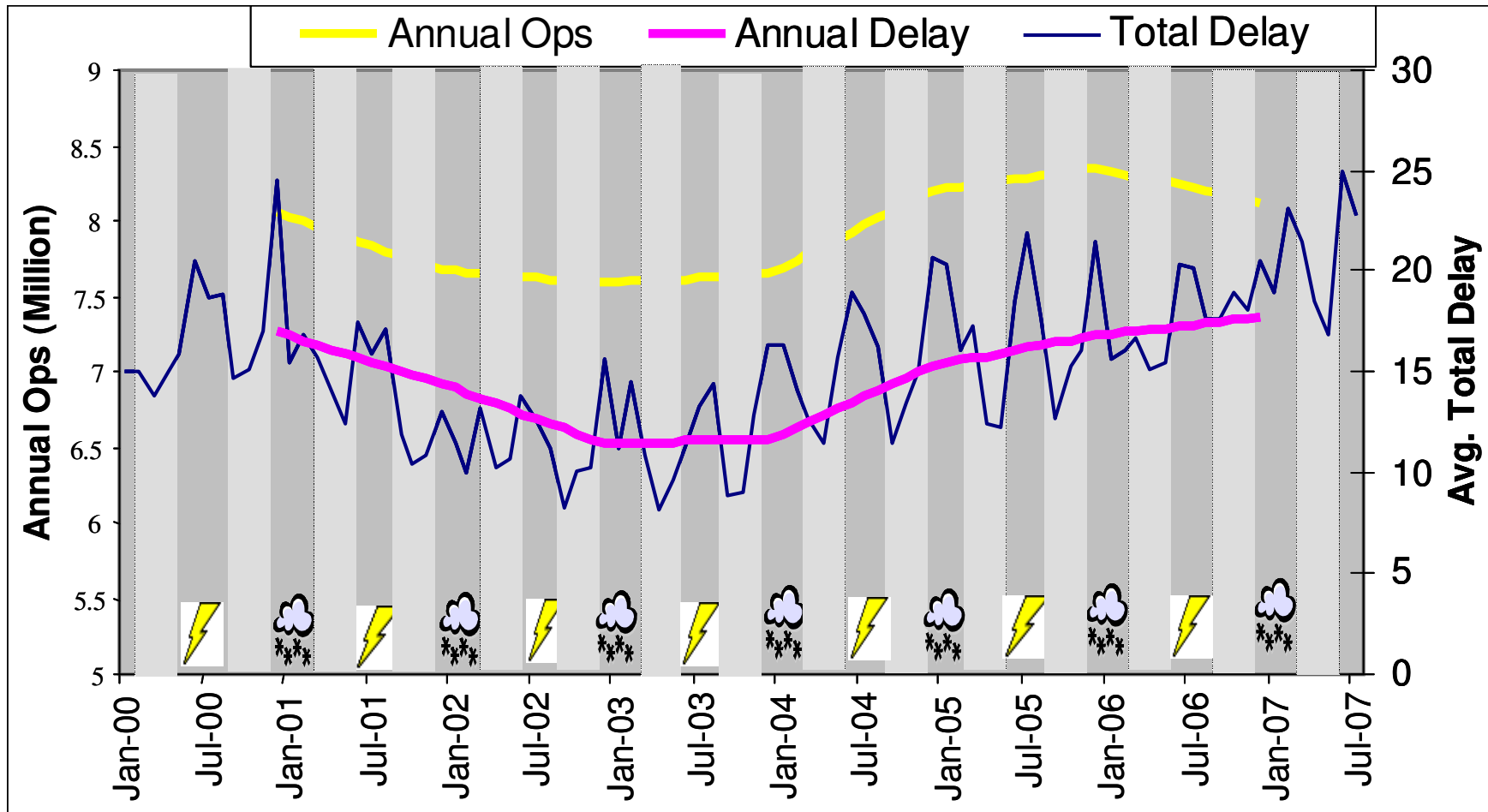
ASQP Delay

- Up ~4%

Total Delay (vs Unimpeded)
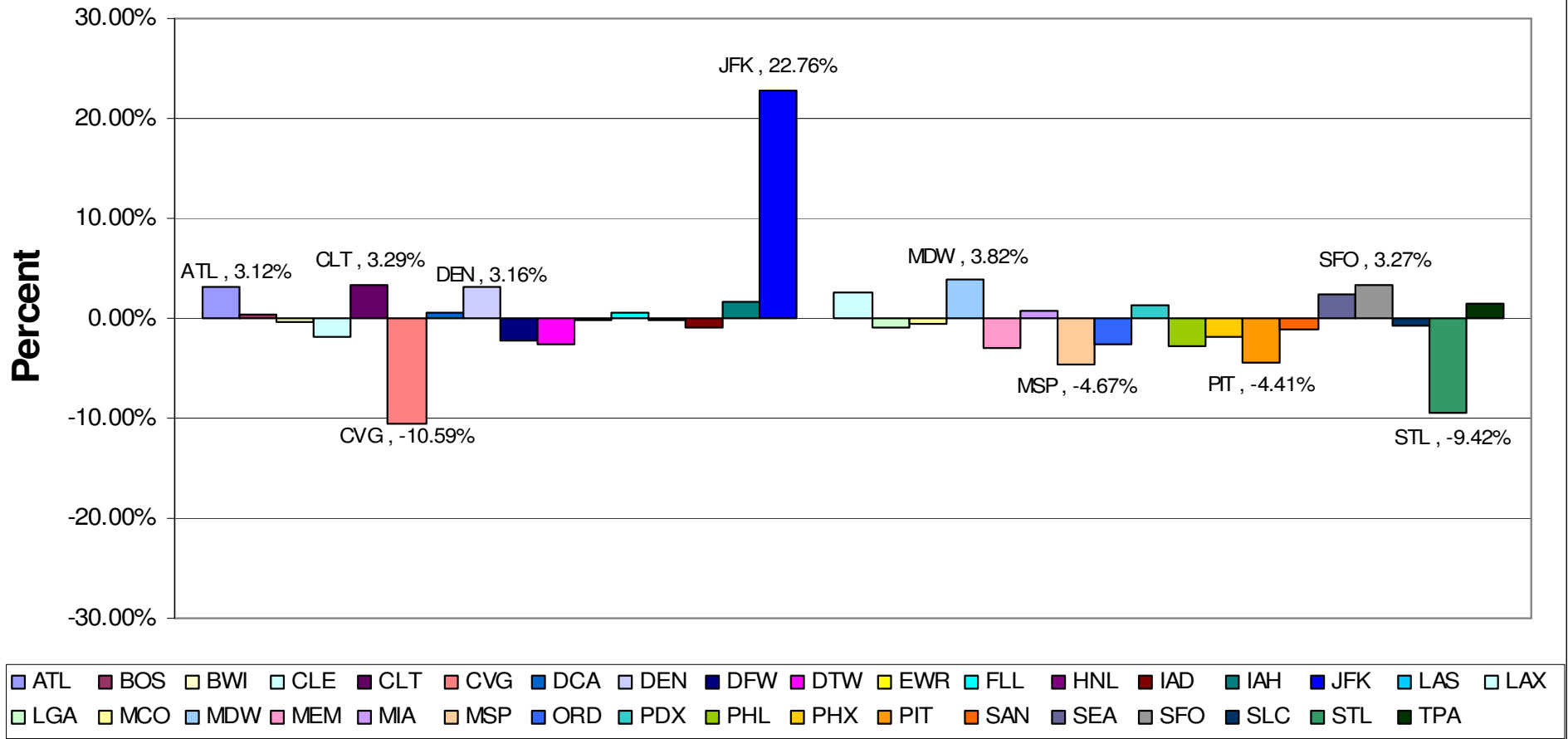
- Up ~3 min

Phase of Flight

- Airborne ~0.3 min
- Taxi ~0.9 min
- Departure ~1.8 min

Demand Down – Delay Up!

Demand is NOT Down Everywhere

Percentage Change in Operations for 35 OEP FY06 vs FY07 YTD JULY Comparison

The "Delta" Performance Metric

Compares each metric component to the average of all equivalent flights.

$$\mu_{ijk} = \frac{\sum\limits_{l=1}^{n_{ijk}} x_{ijkl}}{n_{ijk}}$$

Where x is the flight portion (e.g, block) for flight l and O-D pair ij within month k and n is the number of flights
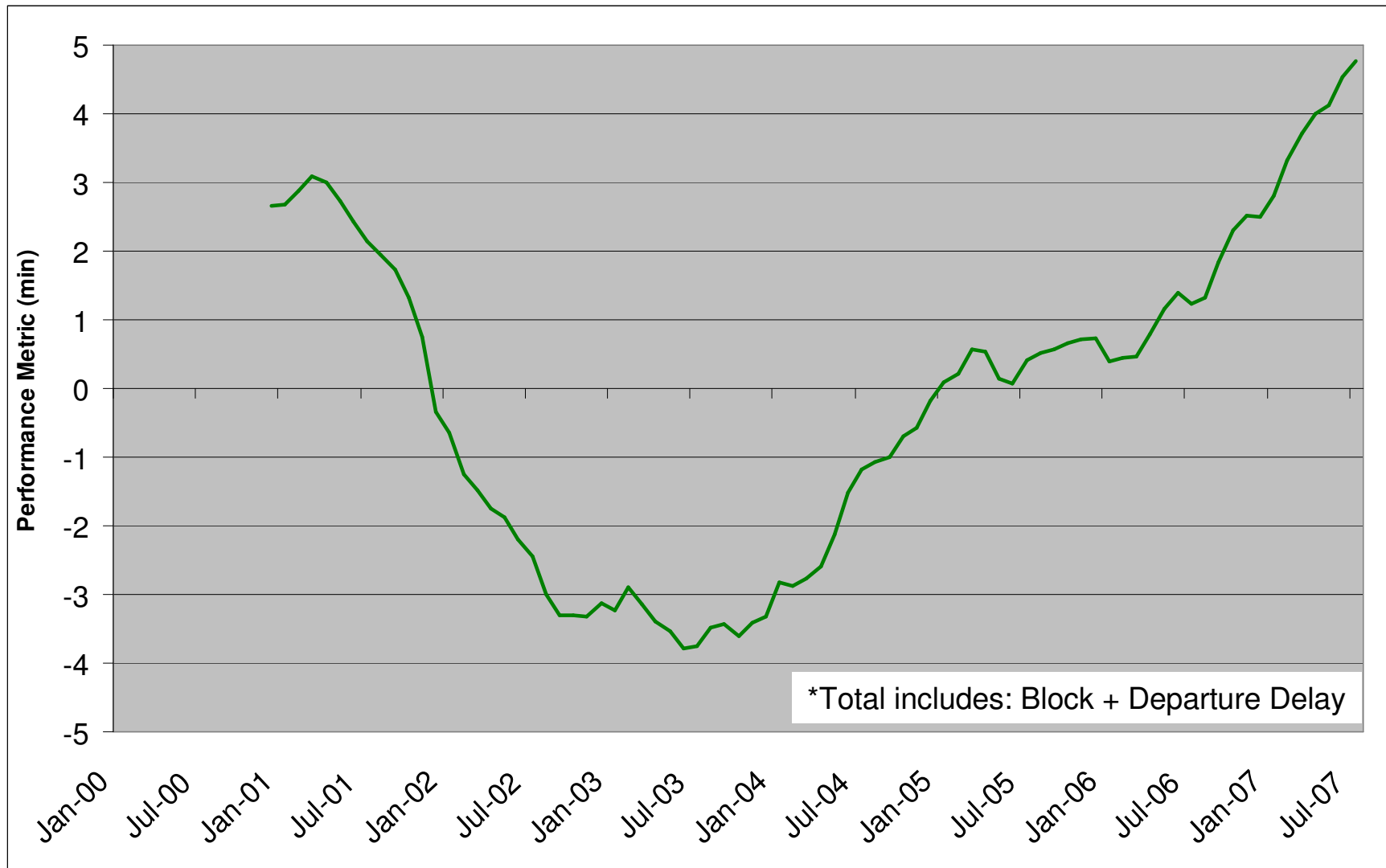
$$\hat{\mu}_{ij} = \frac{\sum\limits_{k=1}^{N} \mu_{ijk} n_{ijk}}{\sum\limits_{k} n_{ijk}}$$

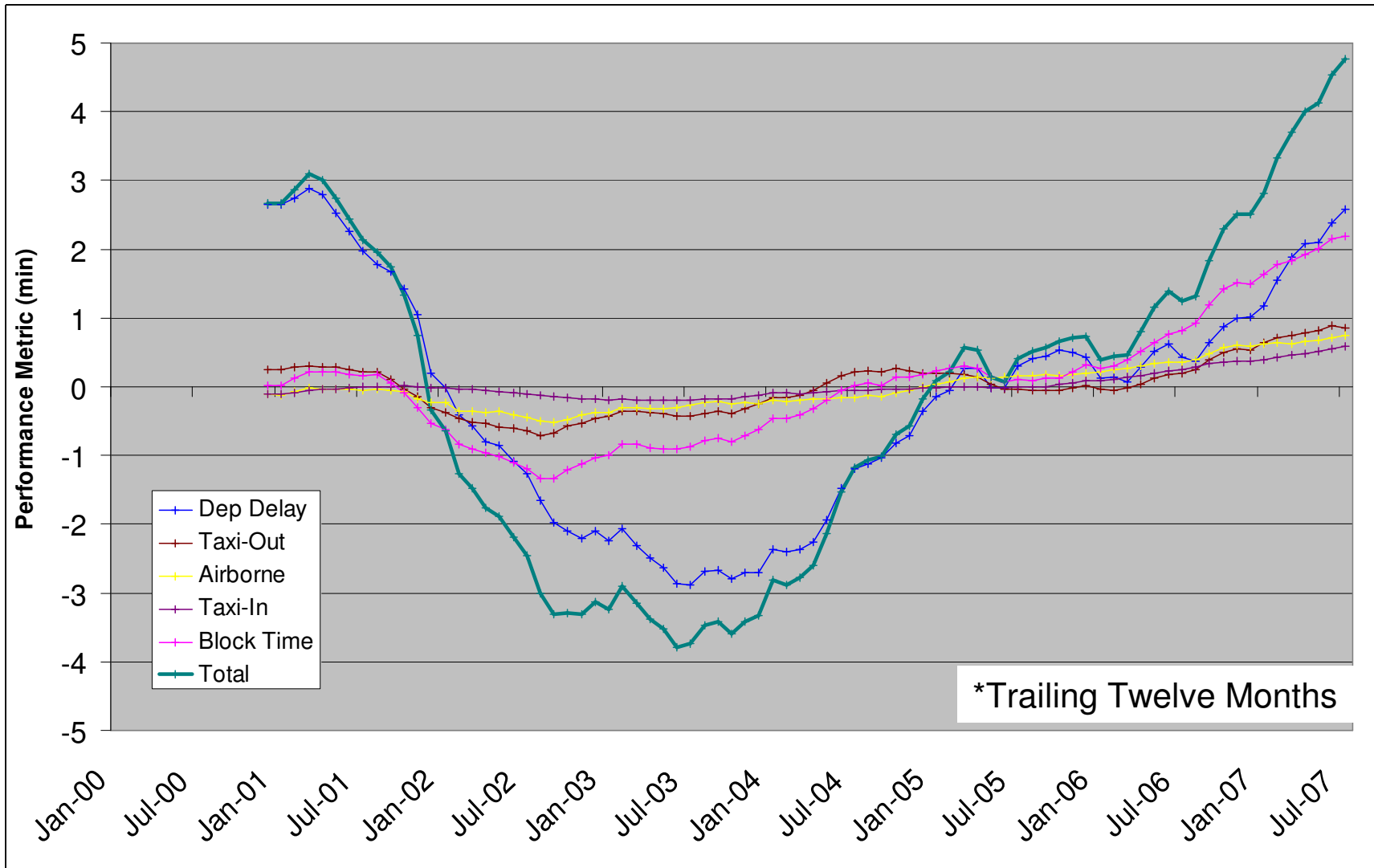A multi-month average block time

$$\delta_k = \frac{\sum\limits_{ij} (\mu_{ijk-} \hat{\mu}_{ij}) n_{ijk}}{\sum\limits_{ij} n_{ijk}}$$

Which is a relative performance metric for the block time that includes ALL flights

Performance Metric Total*

*Total includes: Block + Departure Delay

Performance Metric (TTM*)

*Trailing Twelve Months
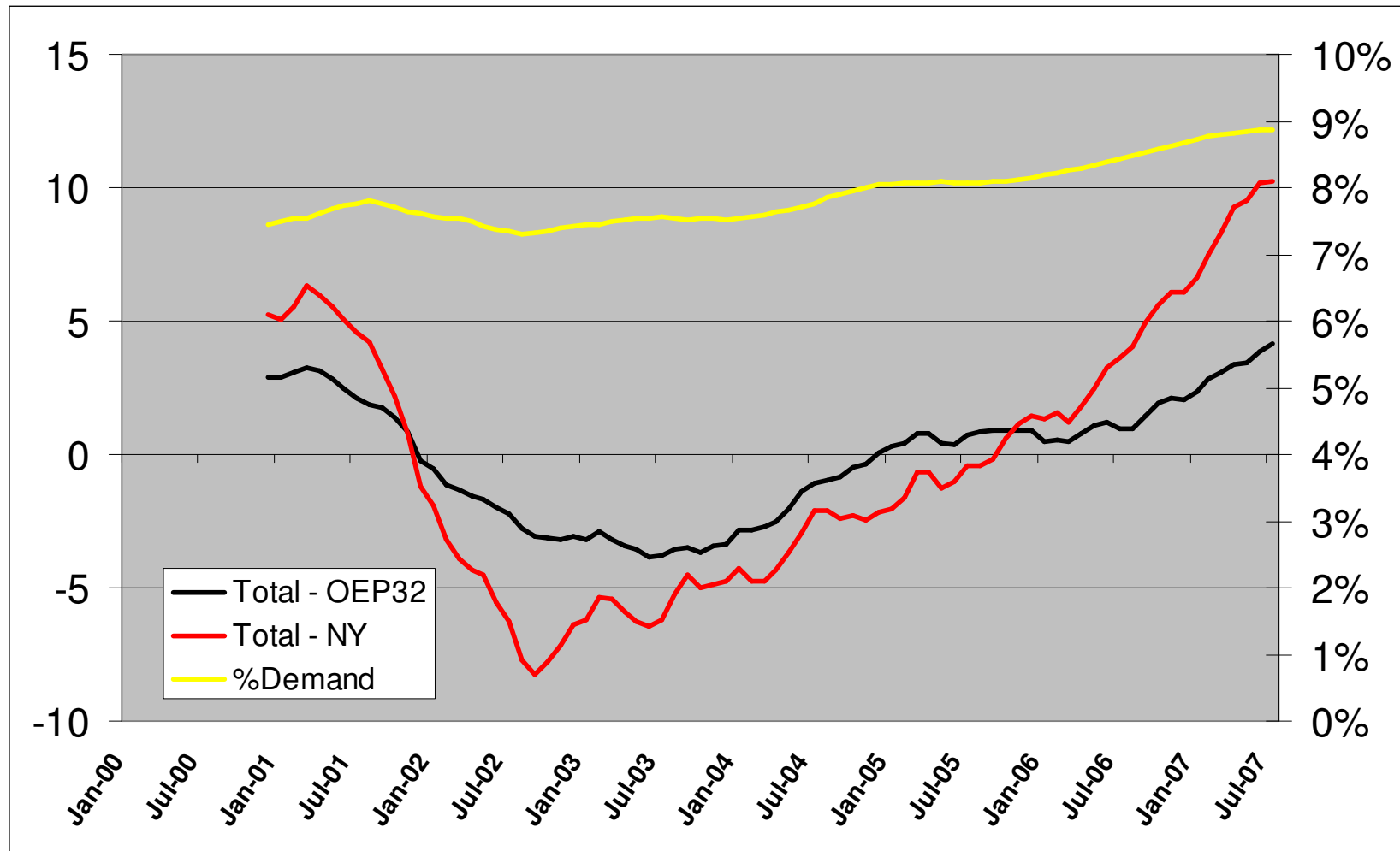
Performance Metric: JFK
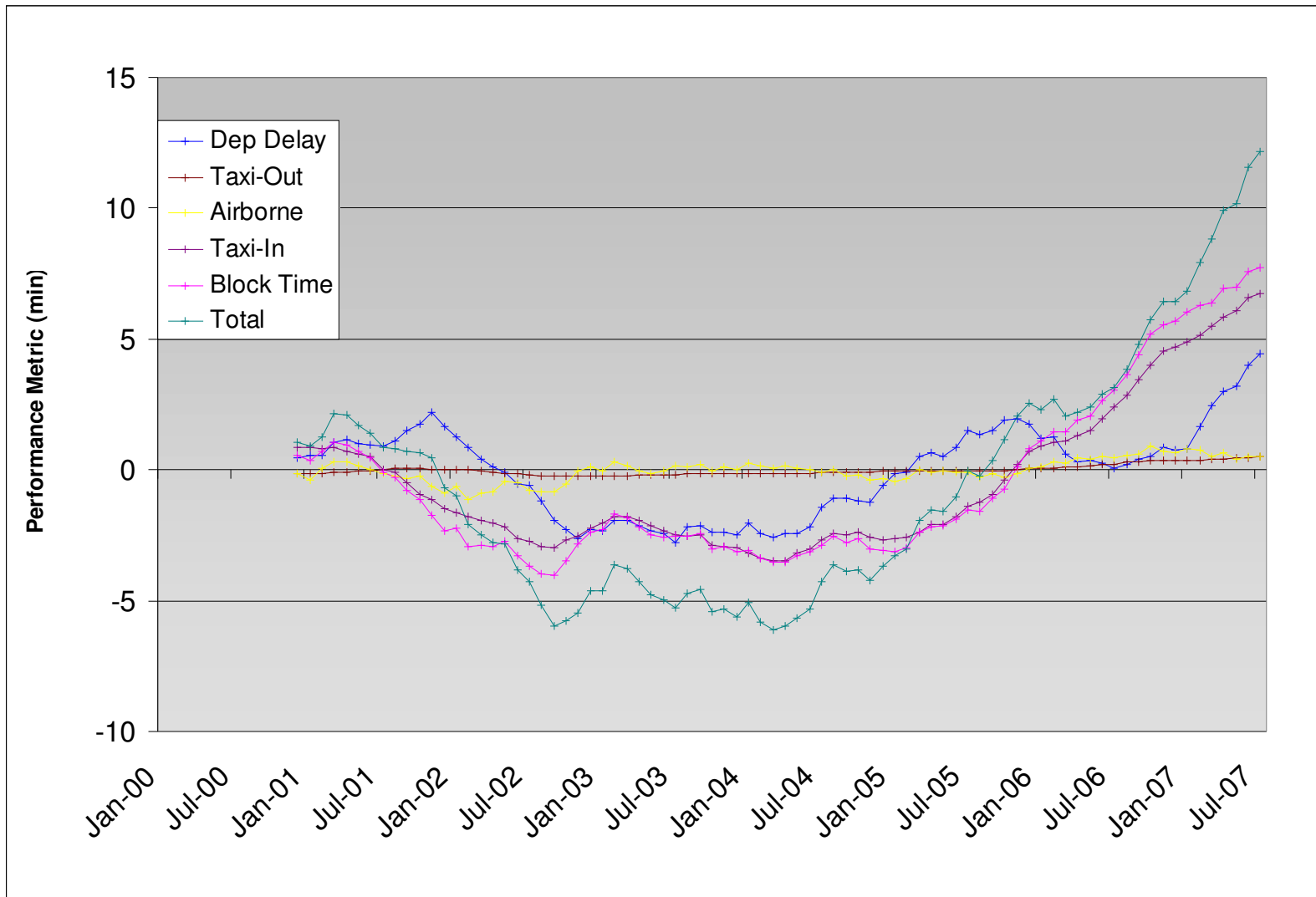
Total Performance - Origin
NY (JFK, EWR, LGA) vs OEP32

Legend:
- Total - OEP32
- Total - NY
- %Demand

FY07 vs FY06 Total Performance (by Origin)

IT'S UP EVERYWHERE?
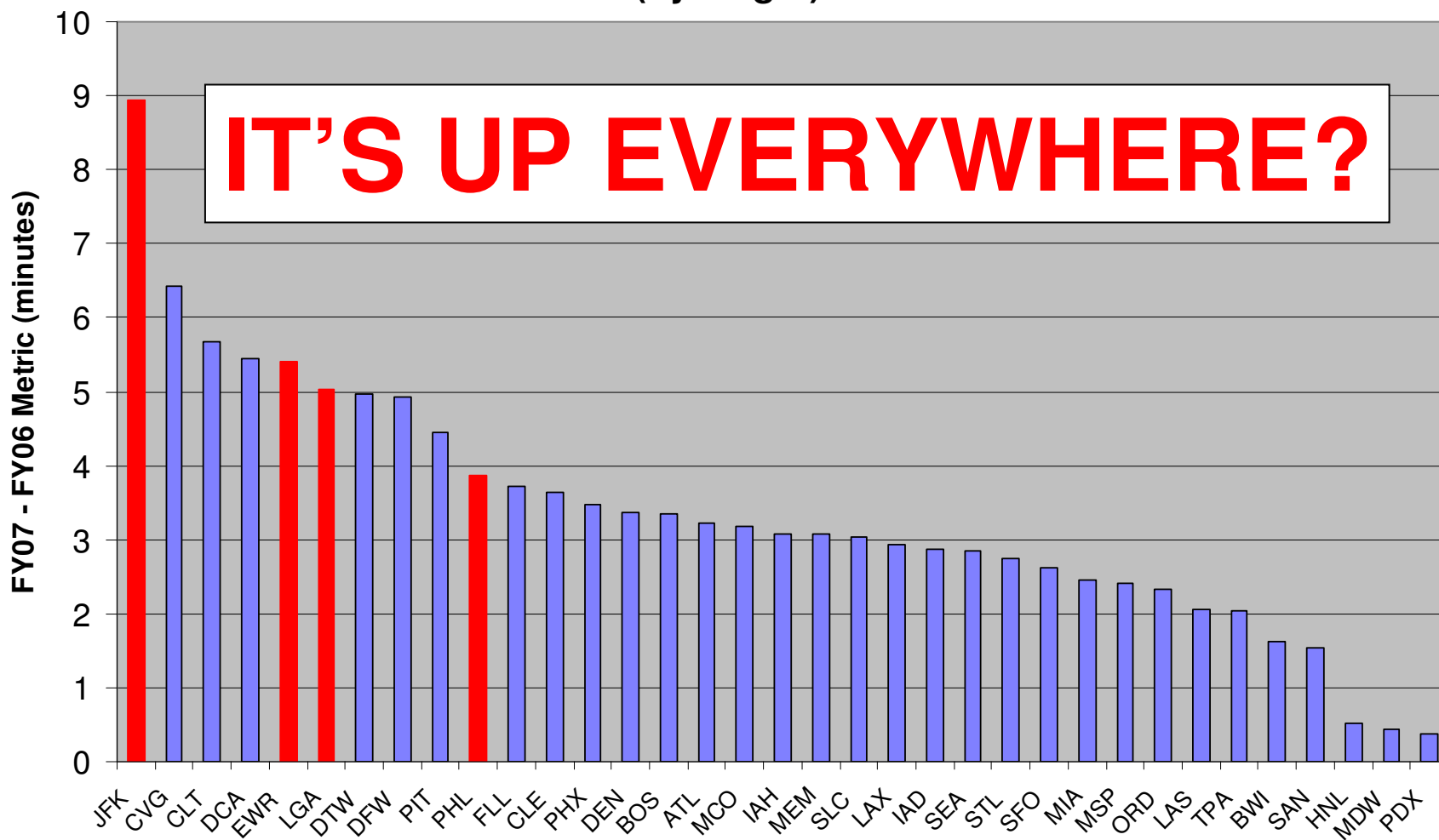
FY07 vs FY06 Total Performance
(by Destination)
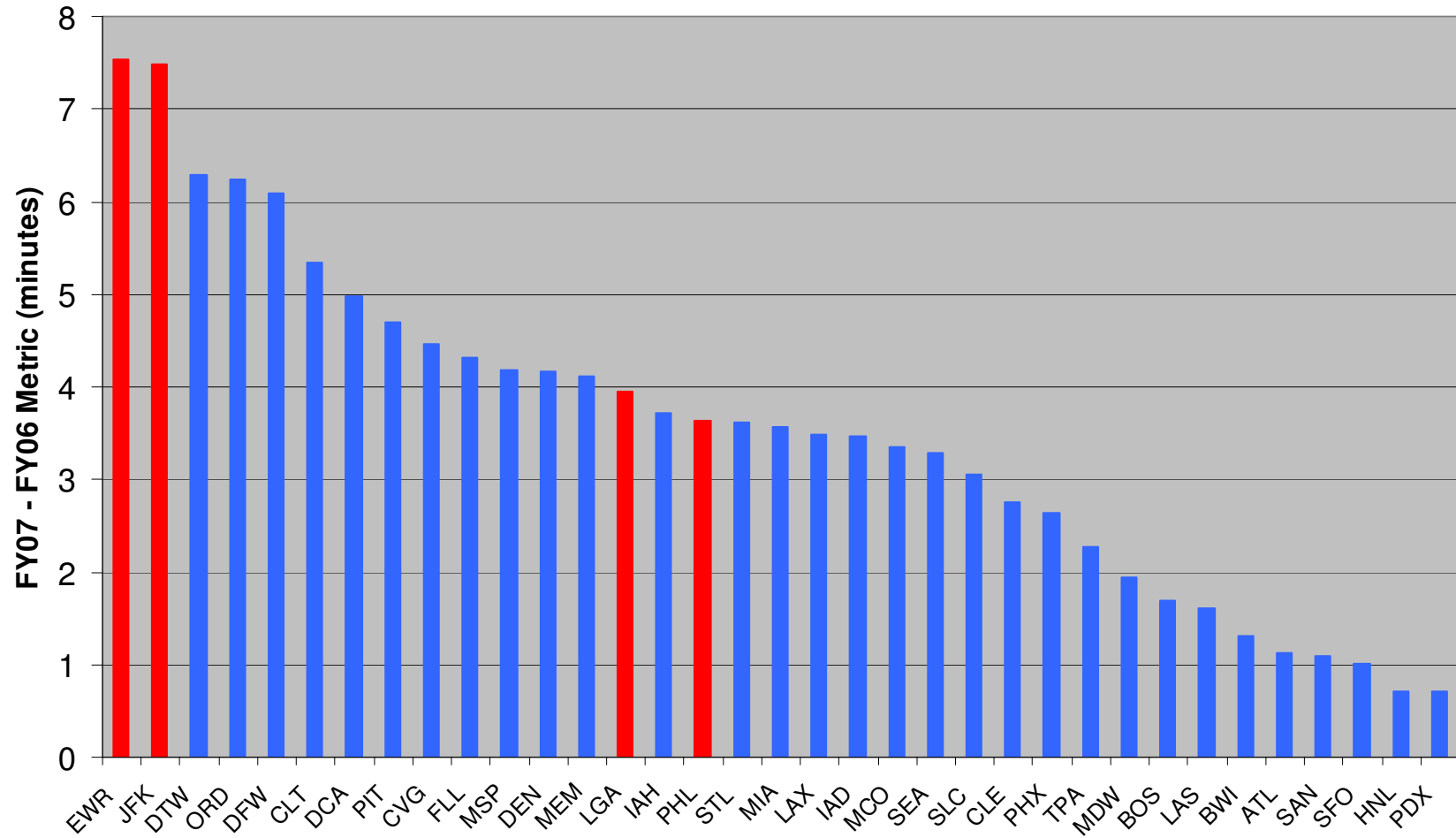
Not Below EVERYWHERE – Inconsistent?

% Change in NAS On-Time (35 OEP) to Individual Target
FY 07 YTD JUNE

Below Target

Above Target

% Change

6.00%
4.00%
2.00%
0.00%
-2.00%
-4.00%
-6.00%
-8.00%
-10.00%
-12.00%
-14.00%
-16.00%

JFK EW LGA CLT DTW SEA DCA ORD BOS DFW PHL DEN PIT CVG IAH MSP MEM PDX PHX LAX FLL LAS SFO MD MCO STL CLE TPA BWI SAN IAD MIA SLC HNL ATL
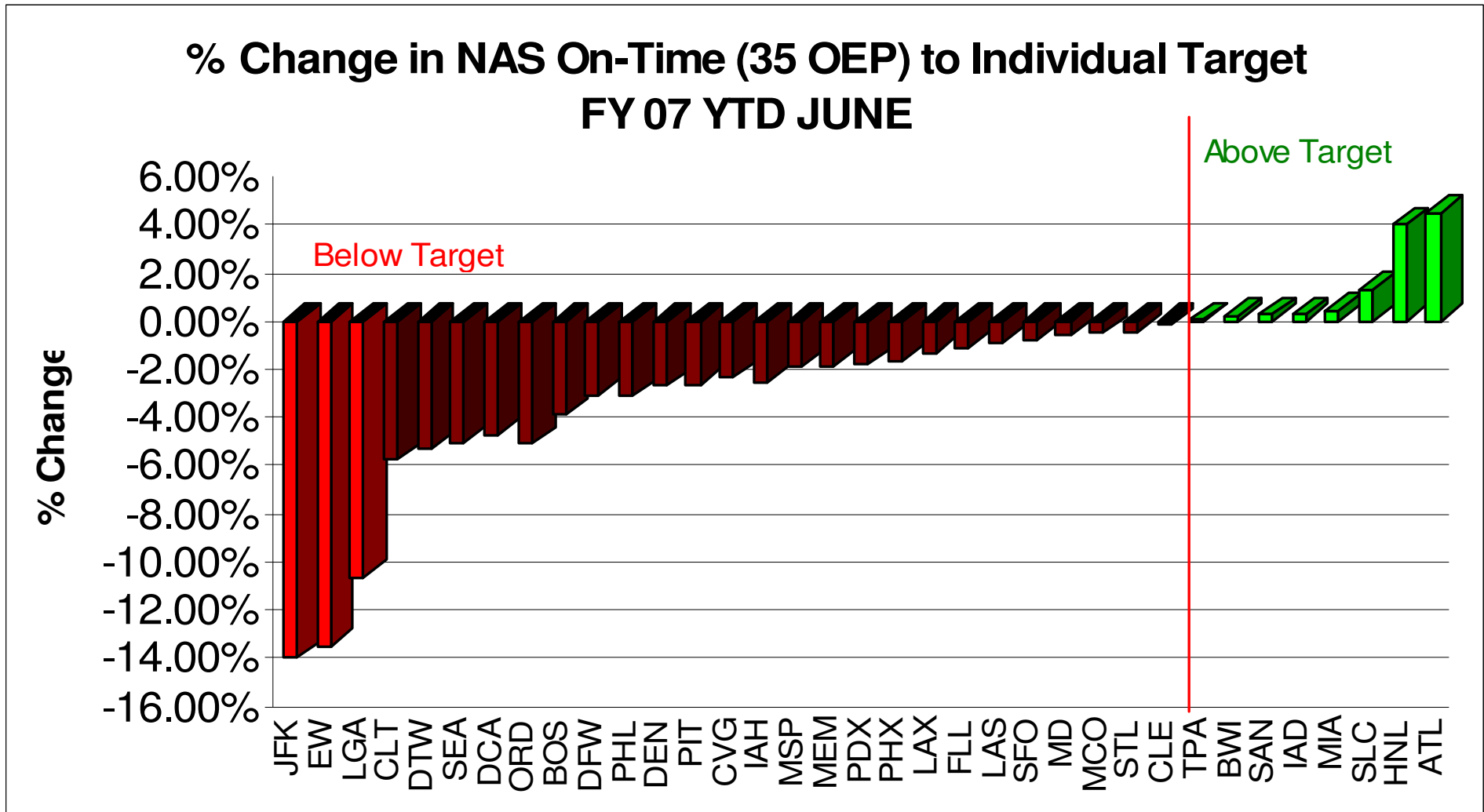
Total Metric Components - Origin

Airborne
Taxi-In
Taxi-Out
Dep Delay

Sorted by Total Metric
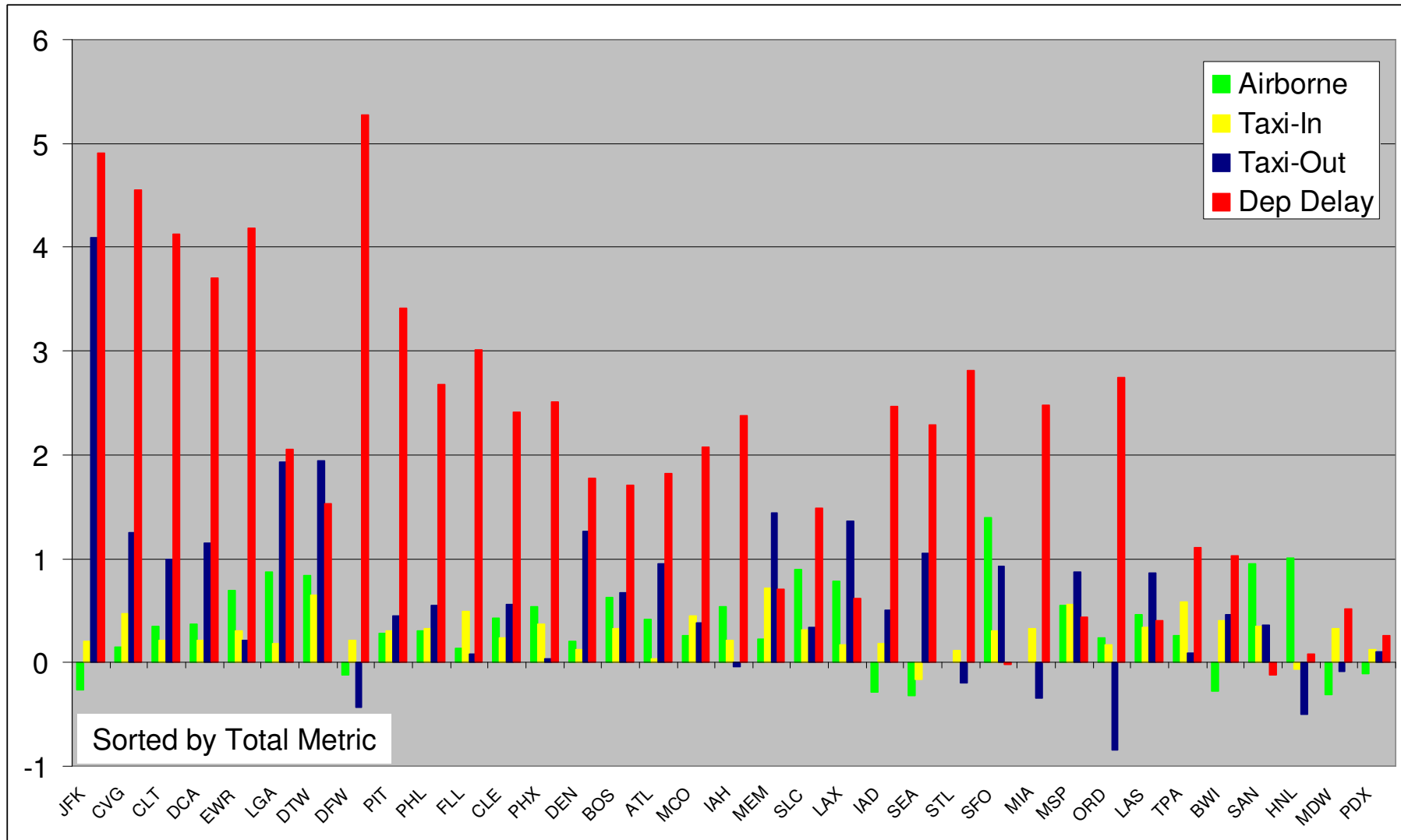
NAS and NY (EWR,LGA,JFK) WITI, Jan 04 - Jul 07 Trendlines: 4-order polynomial

NAS and NY ASPM WITI (Wx Index), Monthly Averages + Trendlines, Jan 2004 - Jul 2007
Normalized vs. OEP-35 Apr-Sep 2004-2006 Average (=100)

Legend:
- NAS WITI
- NY WITI
- Poly. (NAS WITI)
- Poly. (NY WITI)

Y-axis: Normalized WITI
X-axis: Month
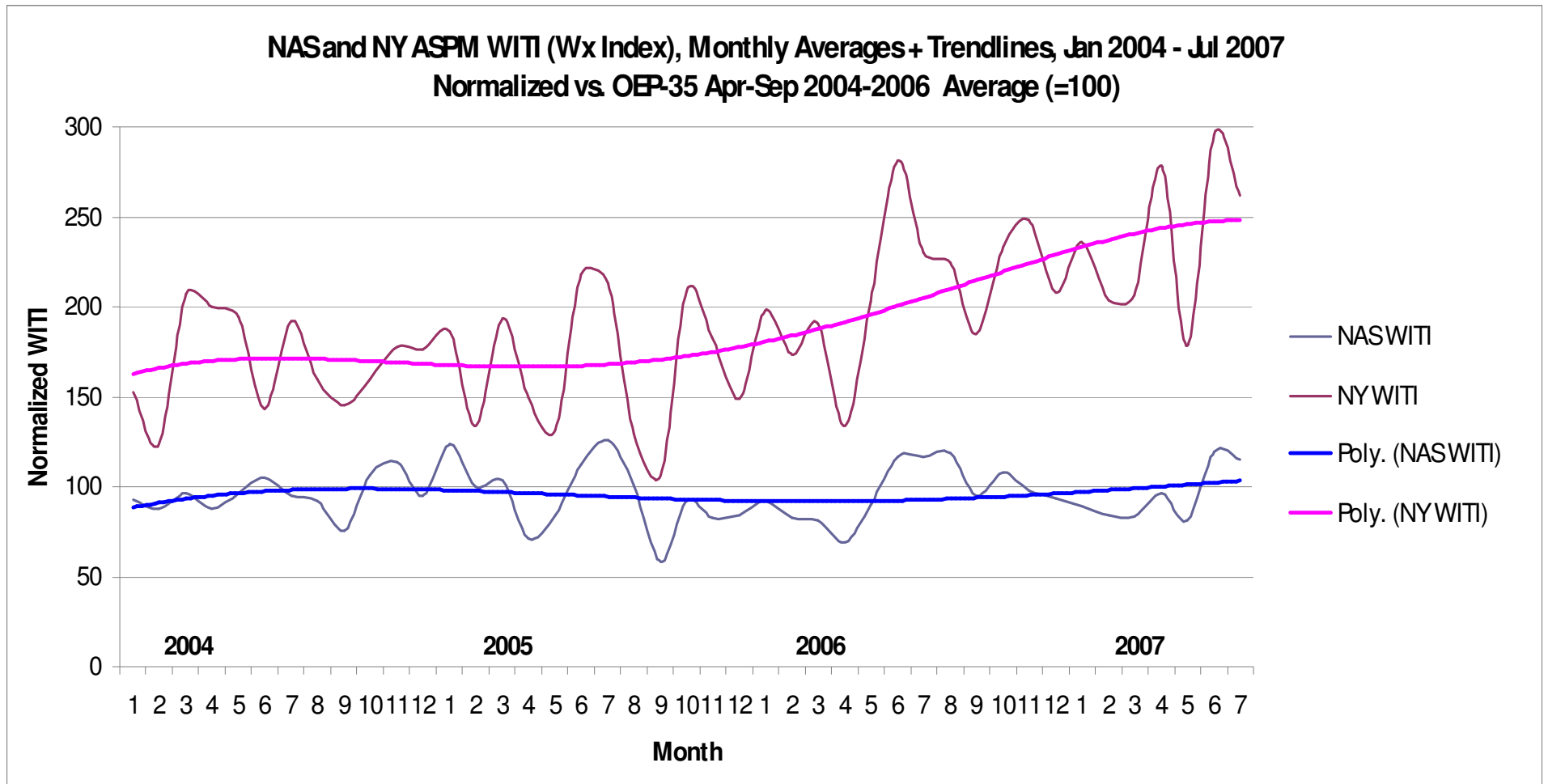
NAS and NY (EWR,LGA,JFK) Delay-to-WITI Ratio Trendlines: 4-order polynomial

NAS and NY Delay/WITI Ratio, Monthly Averages + Trendlines, Jan 2004 - Jul 2007
Normalized vs. OEP-35 Apr-Sep 2004-2006 Average (=100)

Legend:
- NAS Delay/WITI
- NY Delay/WITI
- Poly. (NY Delay/WITI)
- Poly. (NAS Delay/WITI)

Y-axis: **Delay/WITI Ratio**
X-axis: **Month**

Years: 2004, 2005, 2006, 2007
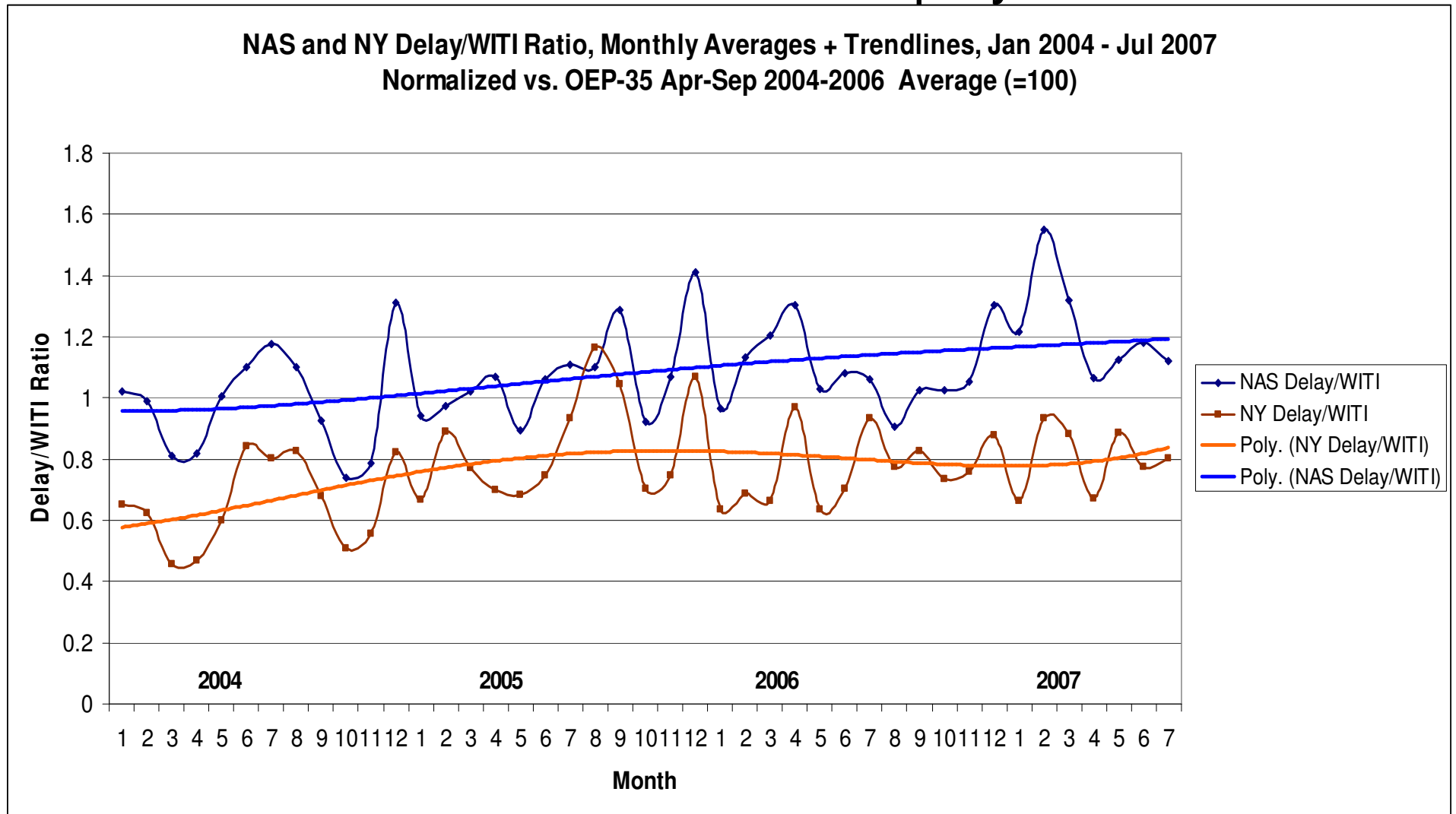
NAS and NY (EWR,LGA,JFK) Cancellations
Trendlines: 4-order polynomial. Source: ASQP

NAS & NY Cancellations as a Percentage of All Flights, Monthly Averages + Trendlines, Jan 2004 - Jul 2007
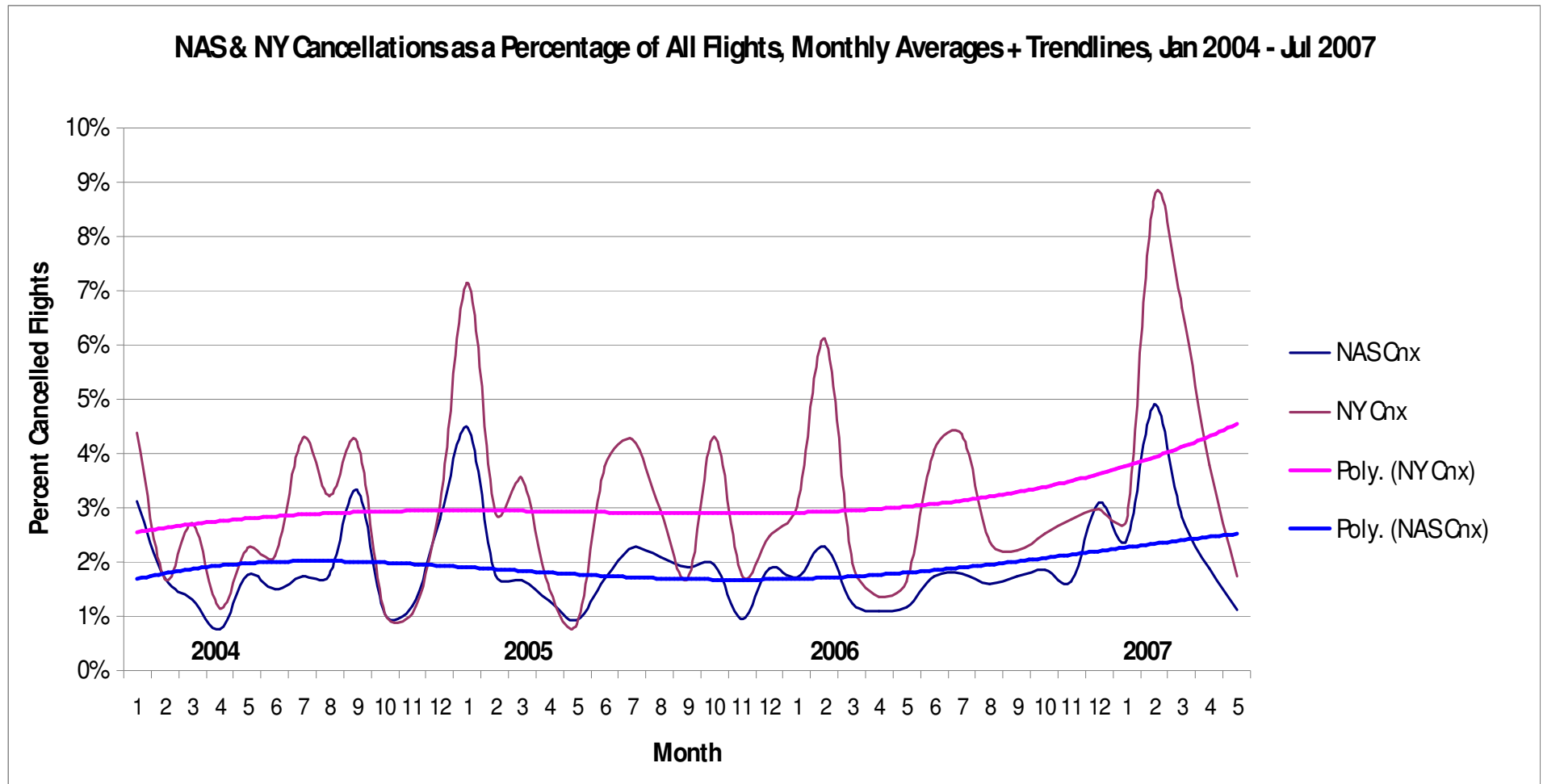
Airlines Causing The Problems?

Legend: CVG Departures-4/19/07 (navy), CVG Departures-4/20/06 (magenta). Y-axis: Departures (0–30). X-axis: time 0:00–23:15 in 45-minute increments.
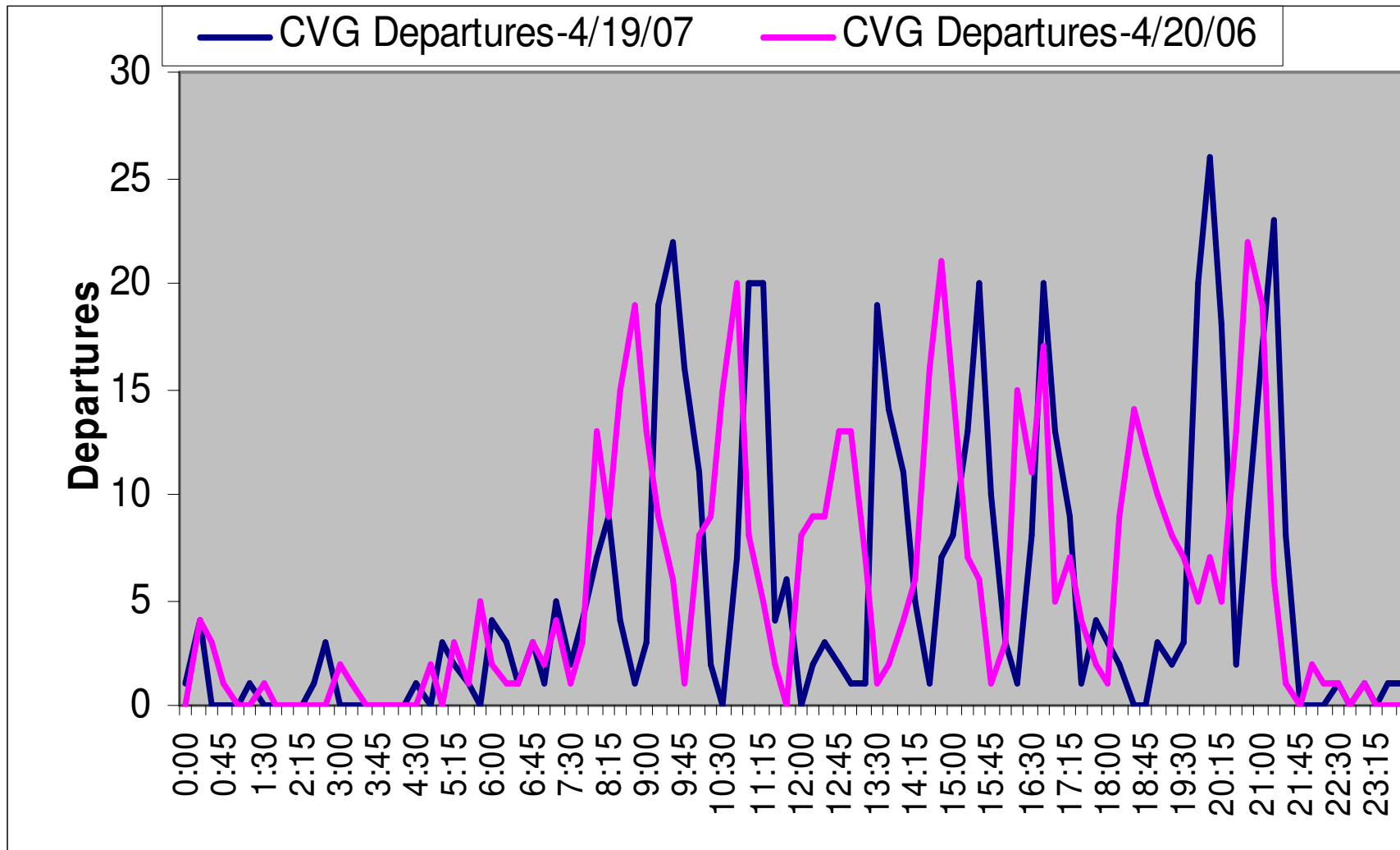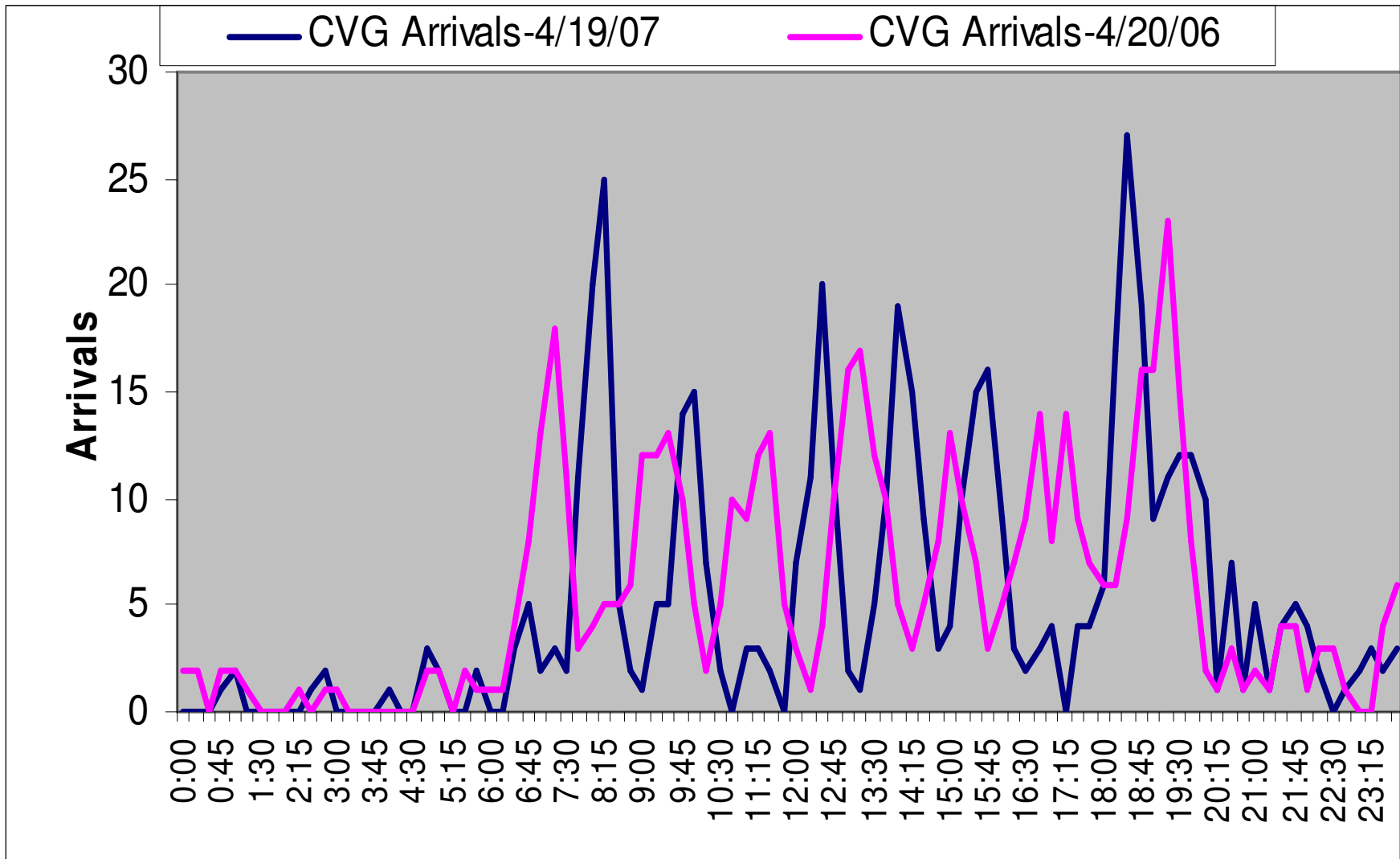
Airline 1 Performance
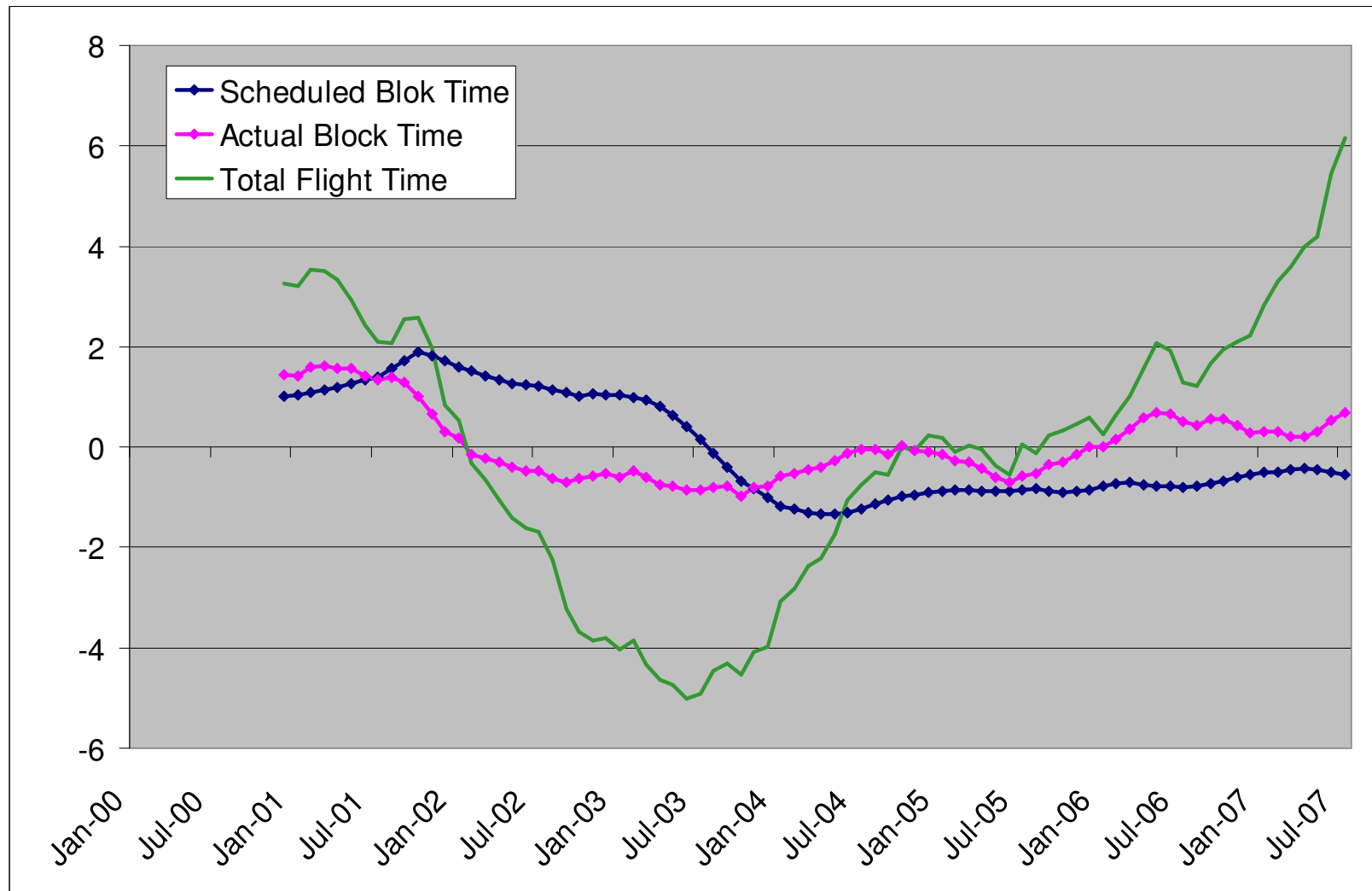
Backup

Airline 2 Performance

Legend:
- Scheduled Blok Time
- Actual Block Time
- Total Flight Time
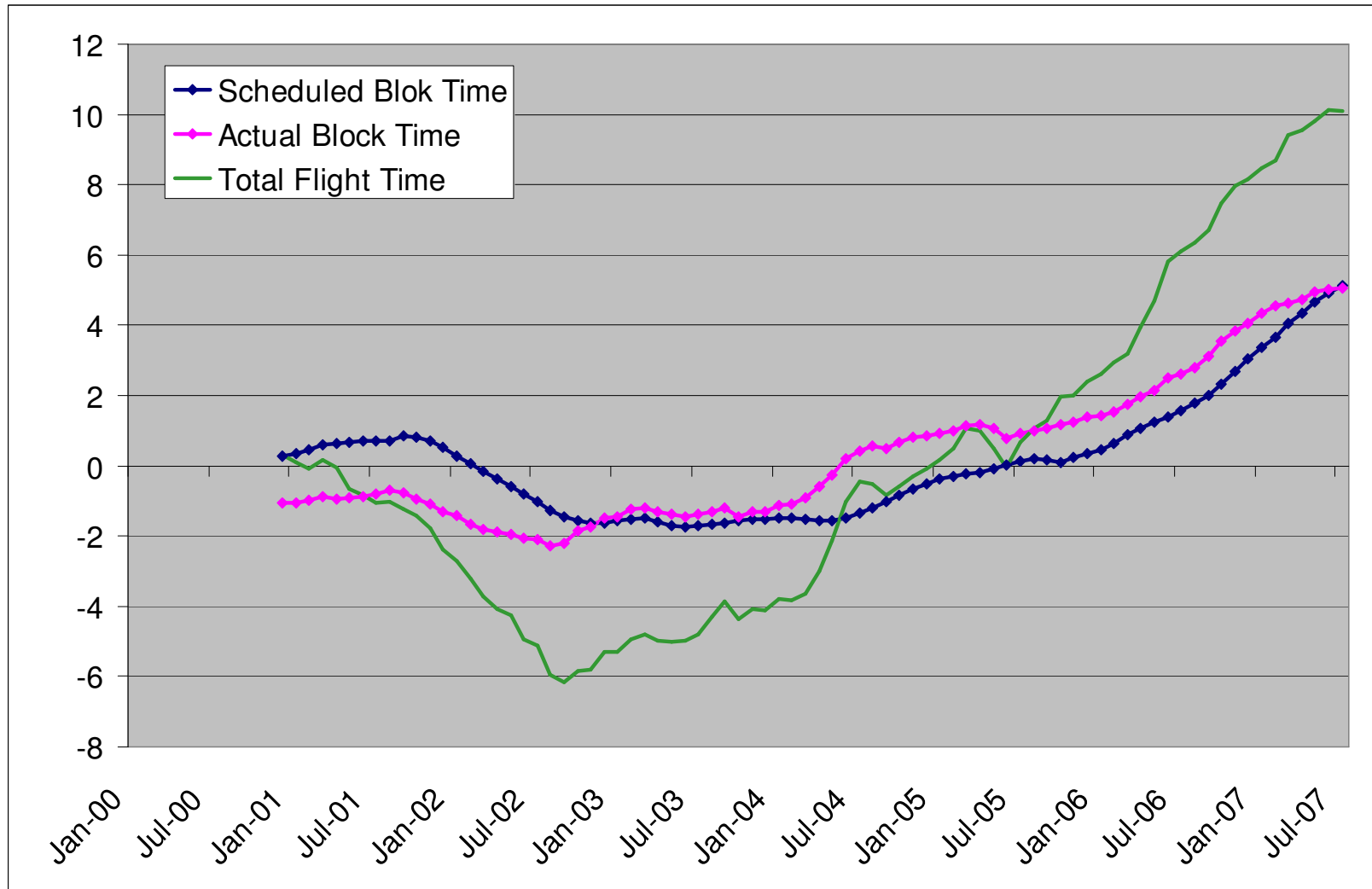
Airline 3 Performance
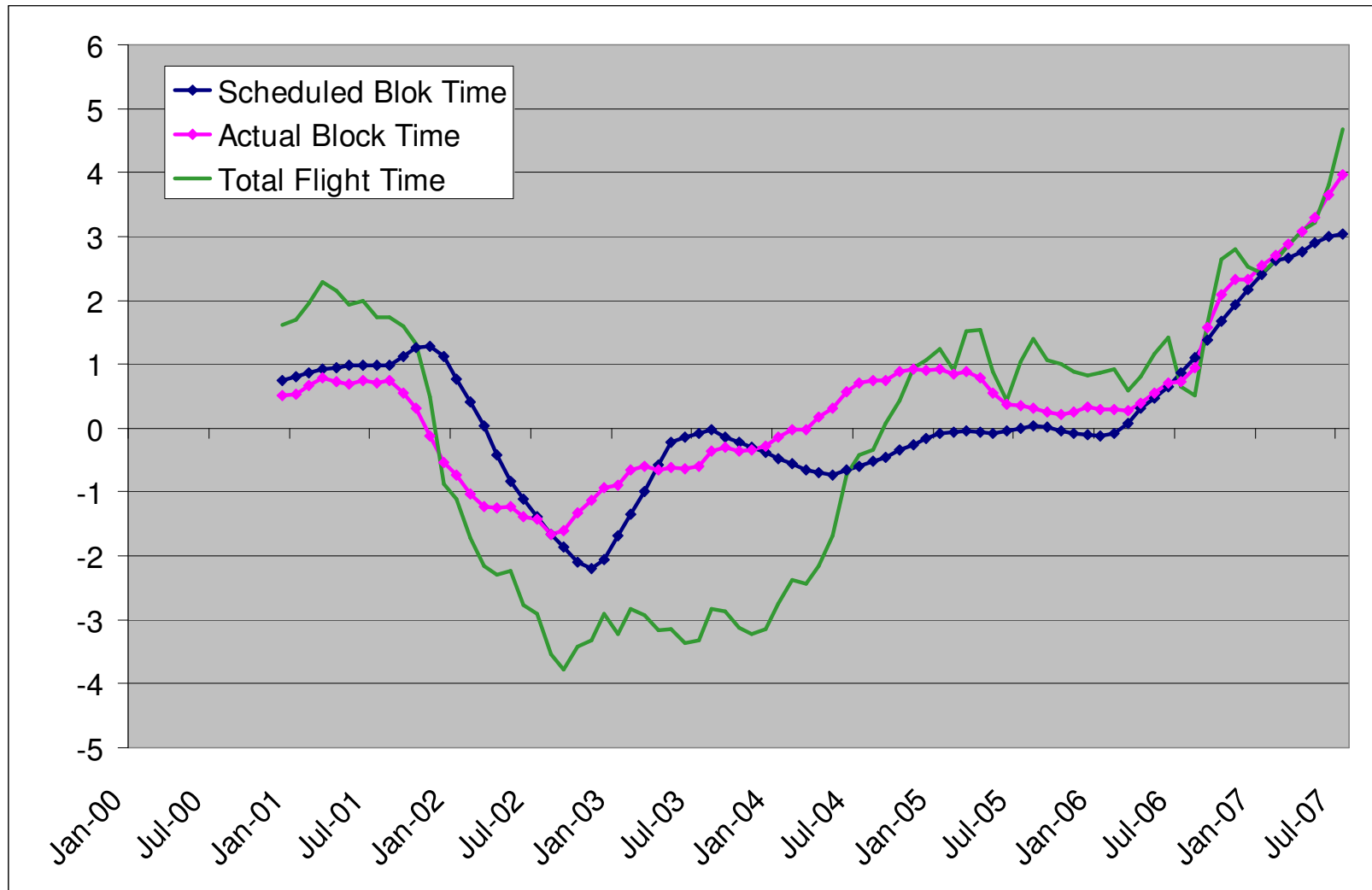
Airline 4 Performance
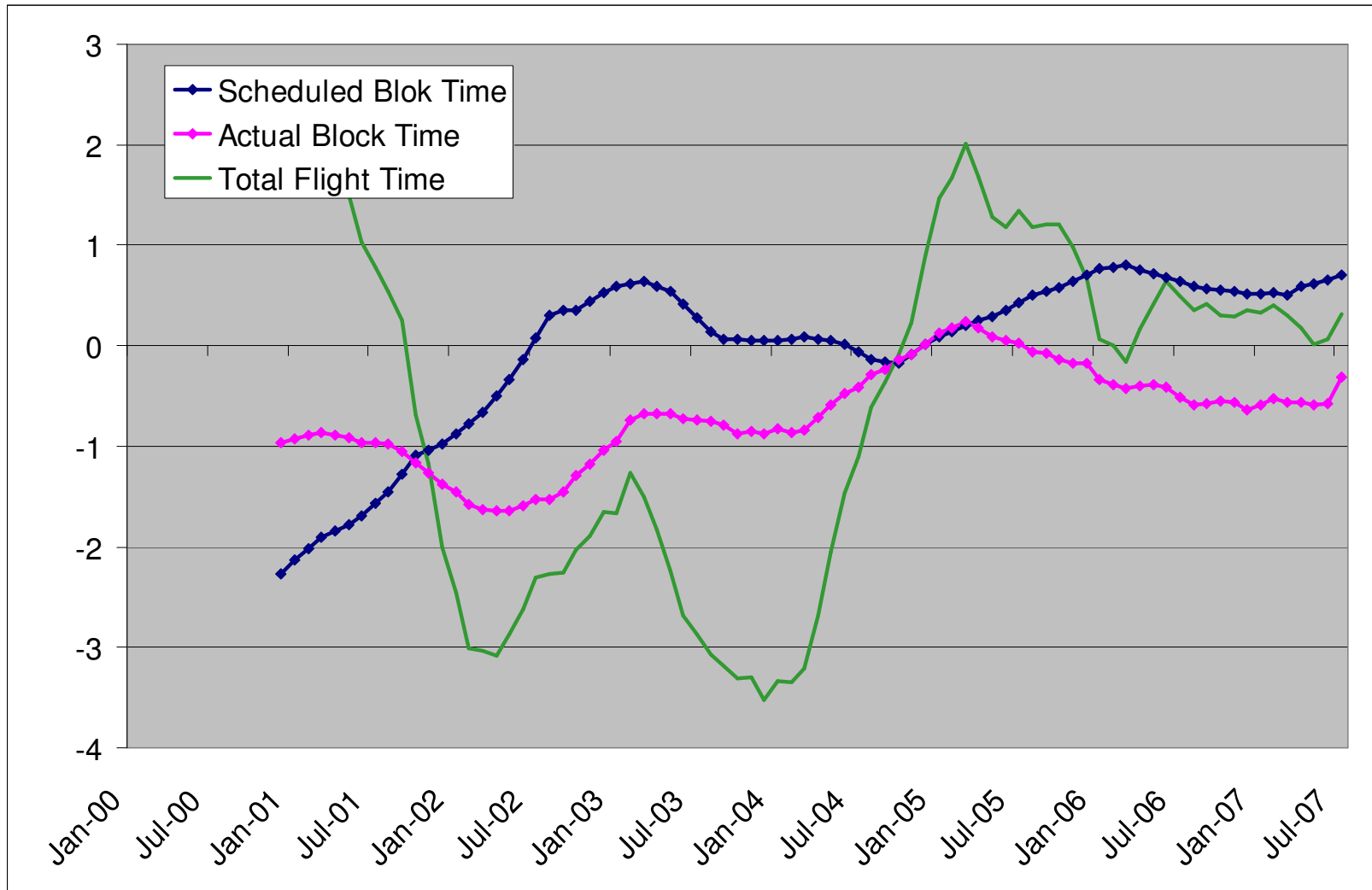
Next Steps

- Follow Aircraft Hulls to Enhance NY as Problem (ASQP or ASPM)

  – Track to Second Level – Is a NY airport late arrival causing the next delay?

- Examine Airports not Achieving Capacity

  – Airport Efficiency Score

  – Why?

Overview

- NAS Weather Index
- Other Delay Measures
  - NAS On time
  - ASQP Carrier Assigned Delay
  - Opsnet Delays
- Relative Performance Metric (Delta)
  - Delay Trends
    - Causes of Delay
    - Metric Results

Performance Metrics Models

Weather

NAS Model

Demand

Trajectories by City pair, time of day, and aircraft type

Outcome

- **Delays**
- **Cancellations**
- **Scheduled Blocktime Changes**
- **Constrained Demand**

Efficiency & Capacity

Terminal   En Route

OEP Solution Sets
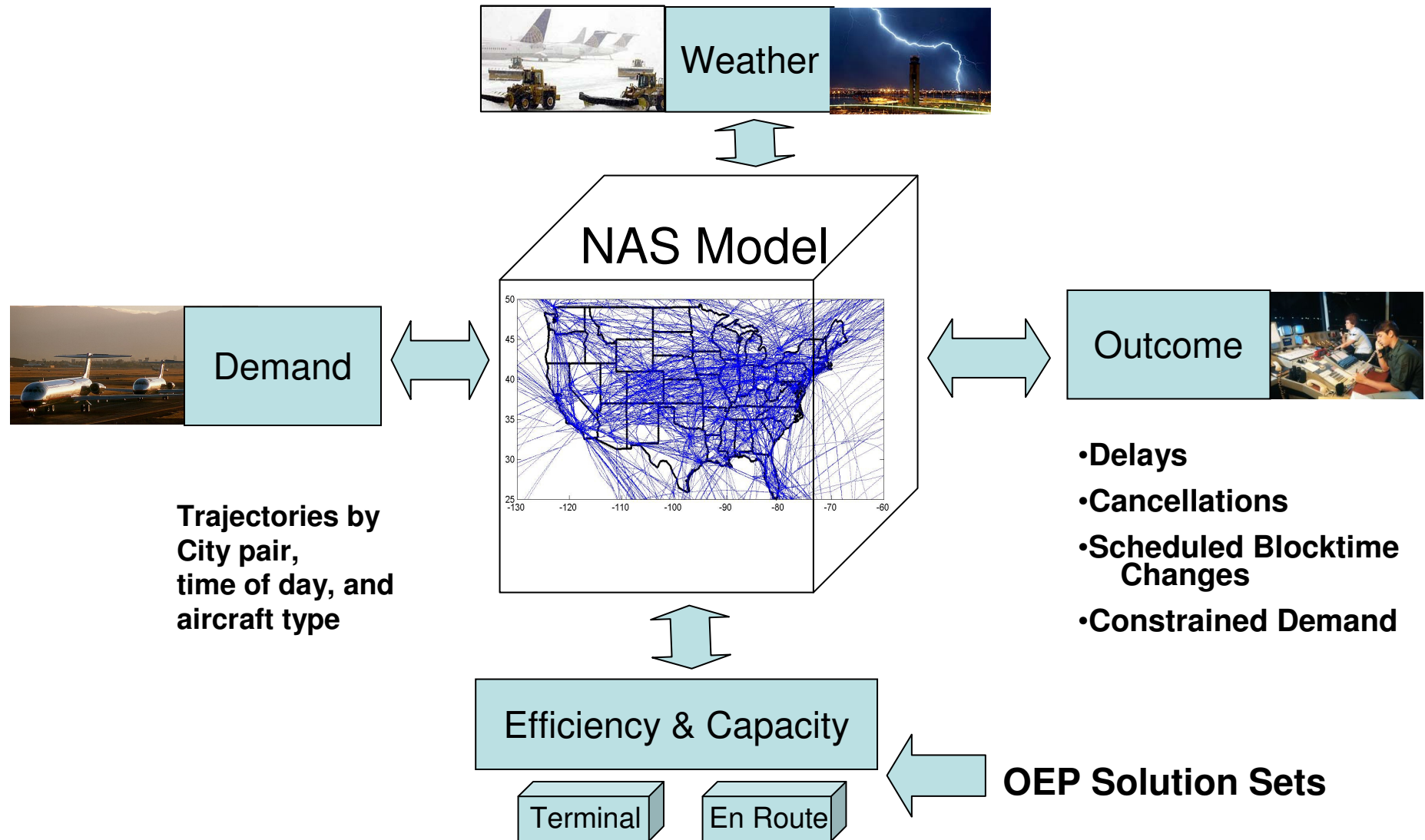
Location of Weather
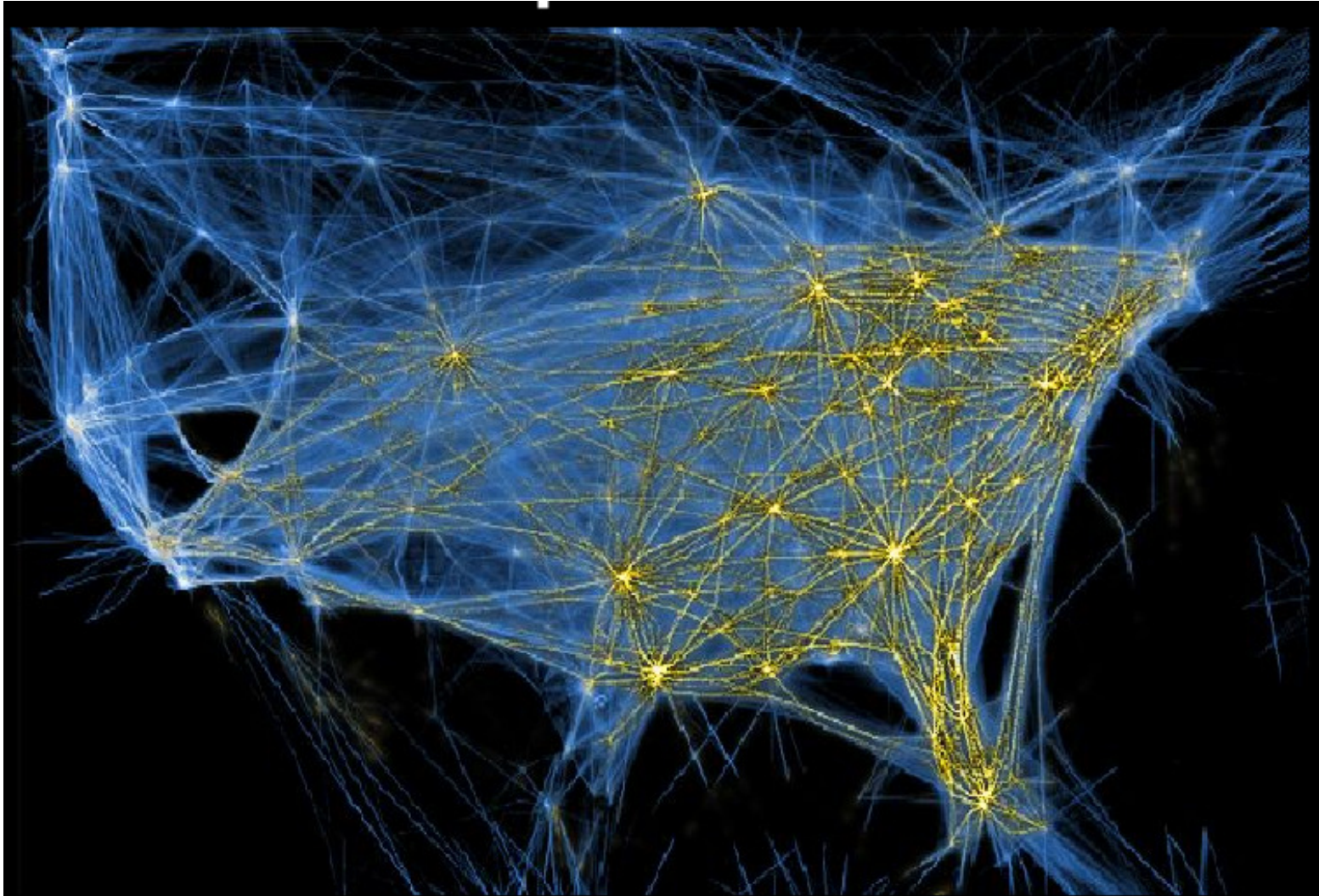
Traffic Component & En-Route Weather

Intended traffic frequency on major routes   **x**   amount of convective weather

STL-ATL: low traffic, thunderstorms en route = modest impact on NAS

ORD-ATL: heavy traffic, thunderstorms en route = significant impact on NAS
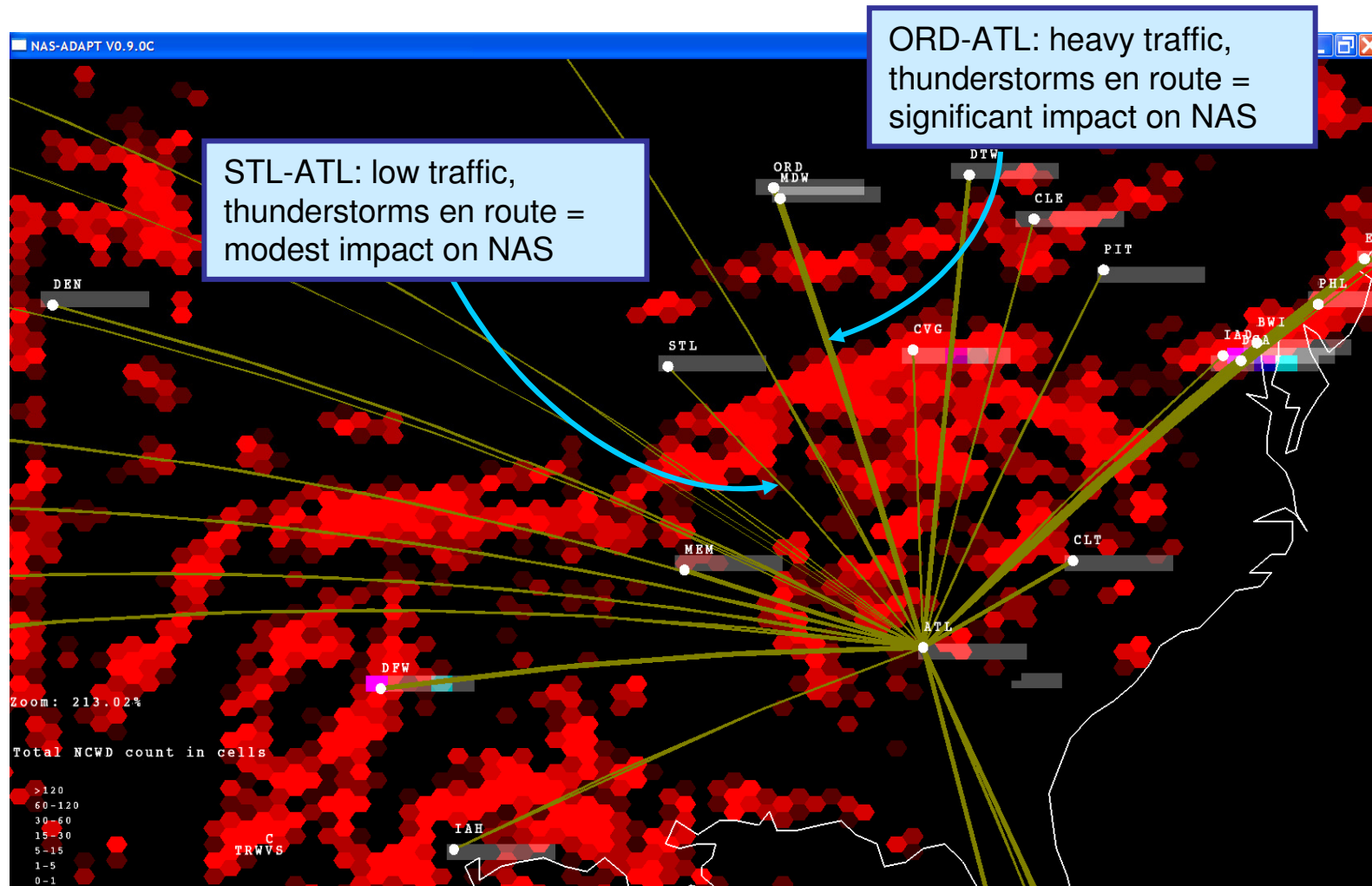
Queuing Delay Buildup Example

Movements per hour

Optimum good-weather capacity

Scheduled traffic demand

Unfulfilled demand

Reduced capacity due to poor weather

Time of day

Hours

Queuing delay

In poor weather

In good weather

Time of day

Cancellations are often used to reduce delays to sustainable levels
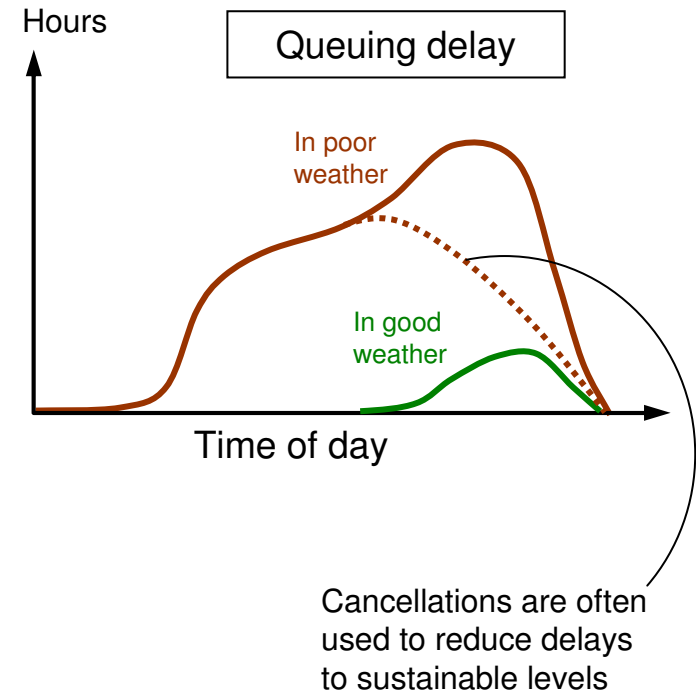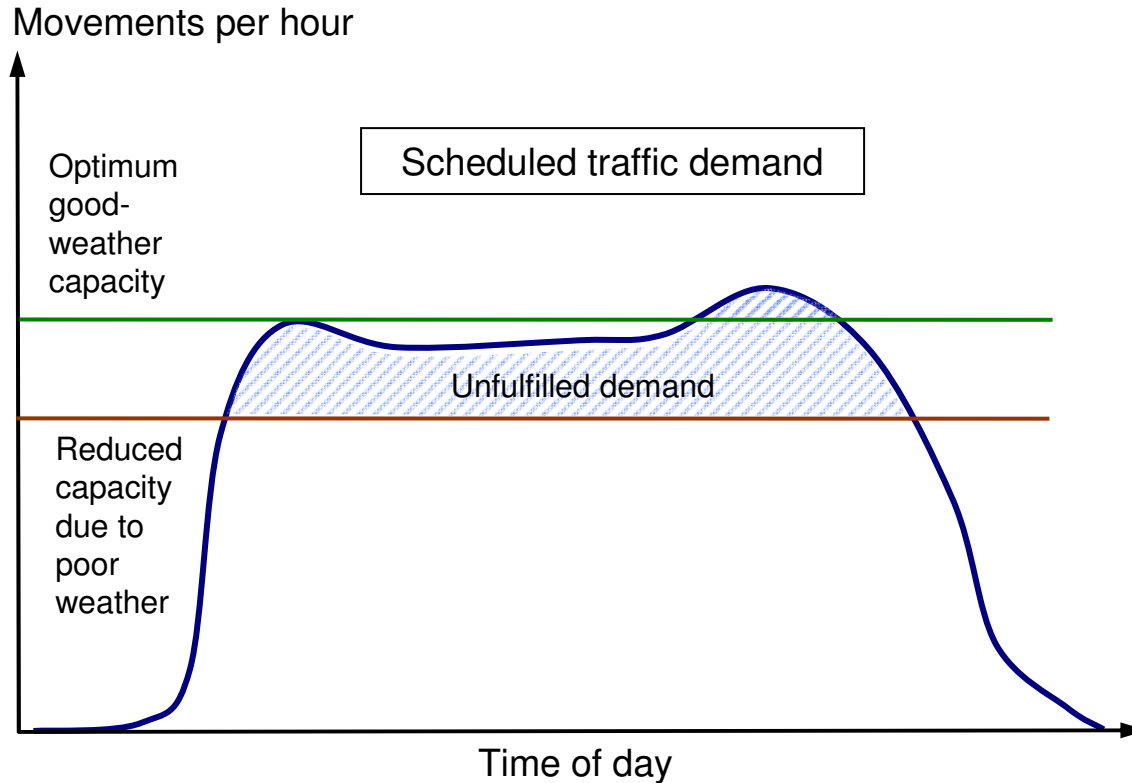
Weekly NAS WX Index and Delay Comparison   Period Ending 08/20/2007
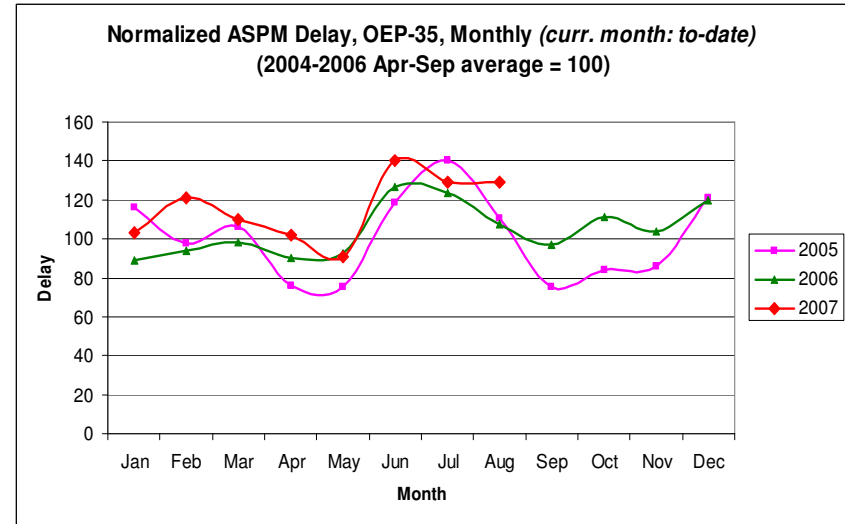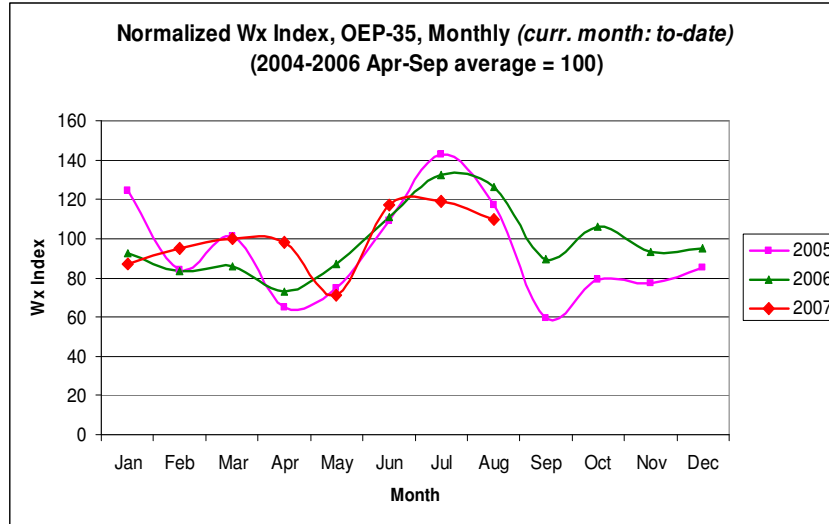
August 2007 is month-to-date as at 08/20

NAS Wx Index Breakdown by Component (Experimental)
Period Ending 08/20/2007

Airport Weather by Category (OEP 35)
Comparison FY06 and FY07 JULY YTD

NAS Wx Index Breakdown by Cause
Explanation to Slides 3 and 4

NAS Wx Index software can distinguish the following factors:

Marked as "Convective"

- <u>En-route convective weather</u>. This shows convective weather impact on an airport's inbound/outbound flows within approx. 500-NM range. This component does *not* affect queuing delay at the airport.

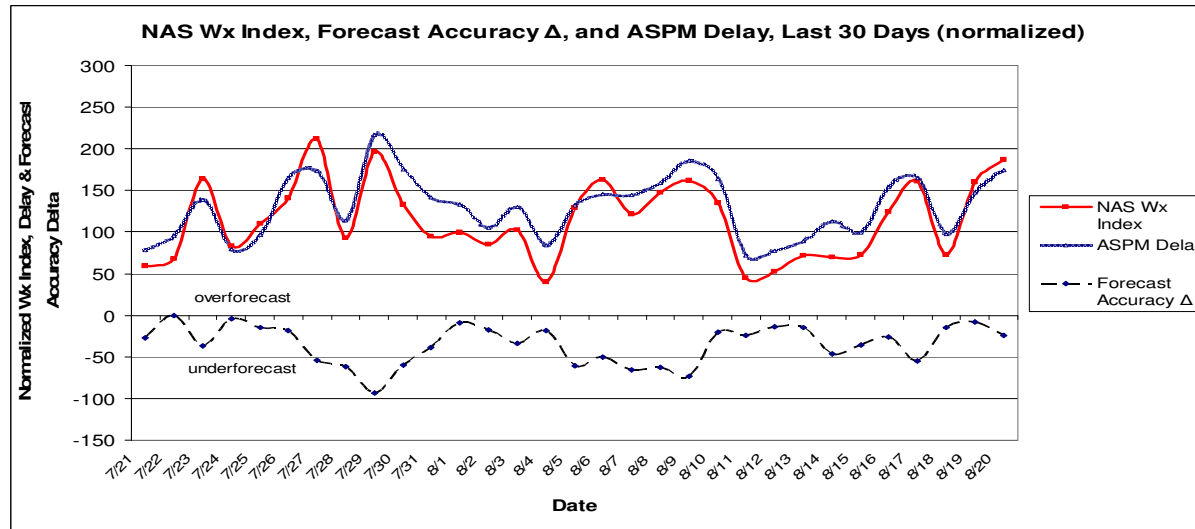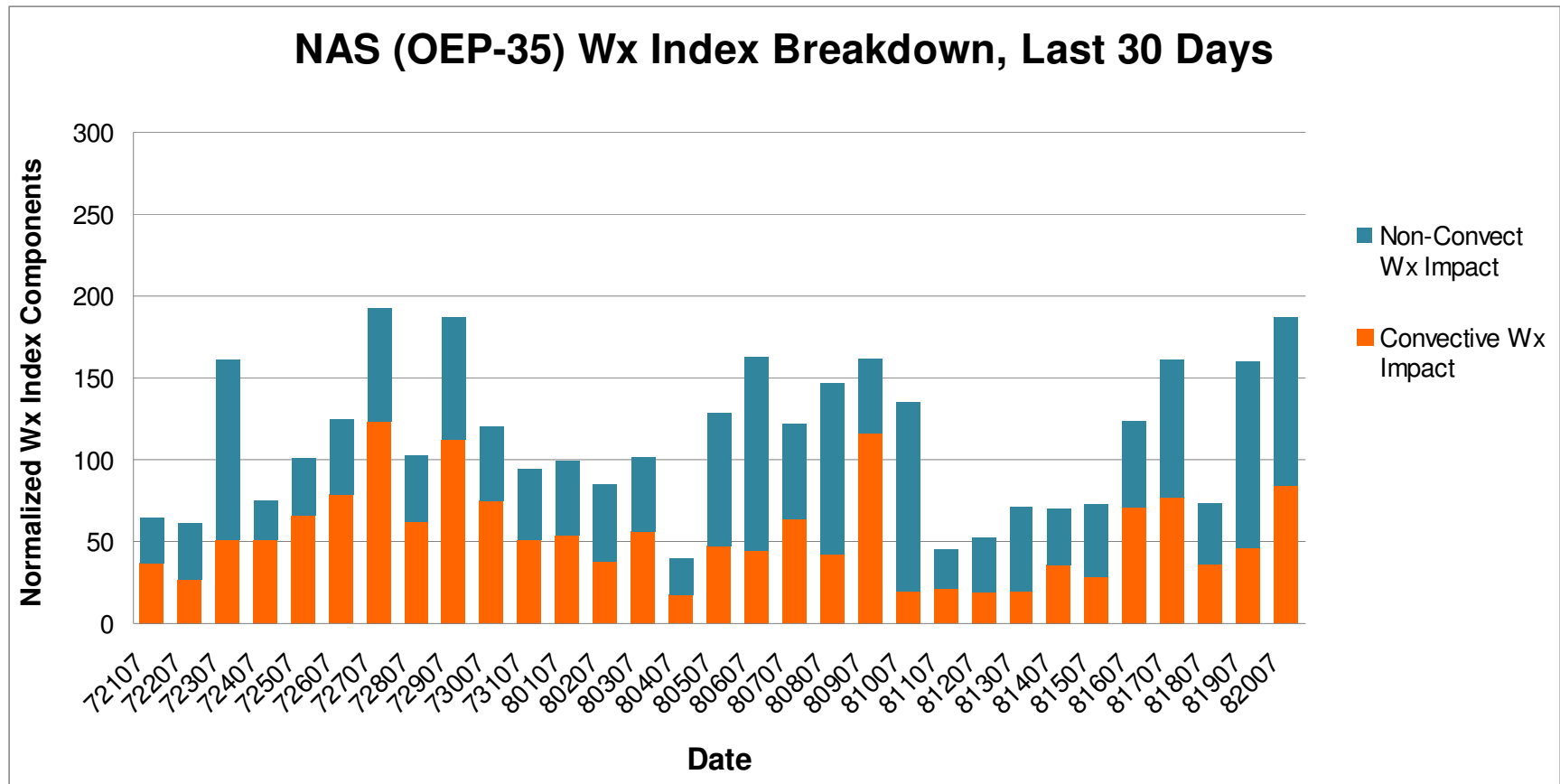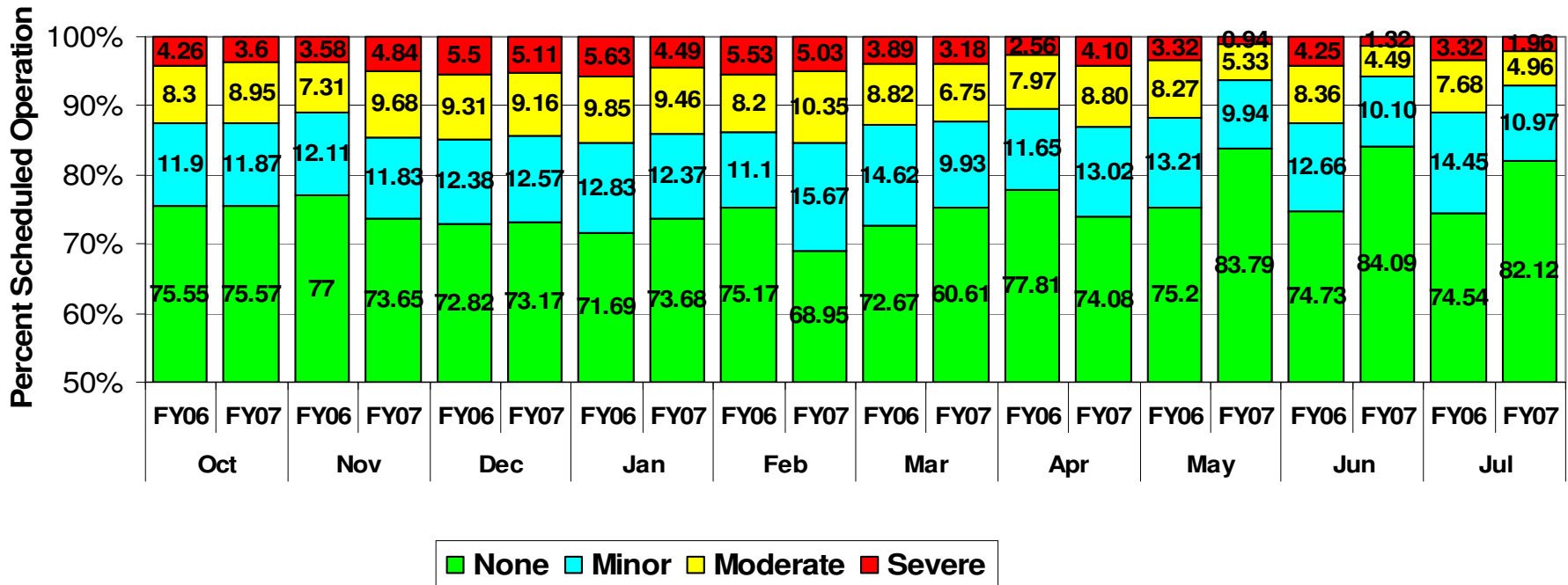- <u>Local convective weather</u>. This reflects how convective weather in the vicinity (<= 100 NM) or directly over the airport reduces airport's capacity. It may affect queuing delay.

Marked as "Non-Convective"

- <u>Wind</u>. Any time there is a wind greater than 20 Kt, or there is precipitation *and* wind greater than 15 Kt, the corresponding impact is recorded. Airport capacity may decrease, i.e. queuing delays may increase.

- <u>Snow</u>, freezing rain, ice etc. The corresponding impact is recorded. Airport capacity may decrease, i.e. queuing delays may increase.

- <u>IMC</u>. Ceiling or visibility below airport specific minima; fog; and heavy rain. The corresponding FAA capacity benchmarks for IMC are used. Queuing delays may increase.

- <u>Queuing Delay (No Weather) plus Ripple Effects</u>. No particular weather factor recorded locally for the given airport / given hour but WITI software computed that there would be queuing delays. This can be simply due to high traffic demand or in an aftermath of a major weather event when queuing delays linger on (even as the weather has moved out).

   Additionally, Ripple Effects are recorded in this component. For example, if ORD experiences departure queuing delays, its corresponding destination airports will get some additional arrival queuing delay.

- <u>Unfavorable Runway Configuration</u>, usually due to light-to-moderate winds (15-20 Kt or even 10 Kt) that prevent optimum-capacity runway configurations from being used. Airports like ORD or LGA are susceptible to this factor. As airport capacity decreases, queuing delays may increase.

Airport Wx Index Breakdown by Hour and by Component: JFK, Aug 17, 2008

JFK Wx Index Breakdown, Aug 17, 2007

Effects of previous IMC + excess traffic demand cause queuing delays

Low CIGS cause a new temporary drop in capacity

Queuing delays are more due to excess demand than to Wx

Some convective Wx

Wind as cold front arrives

Legend:
- Unfav RWY Config
- QDel_no_Wx+RippleEff
- IMC
- Snow
- Wind
- Local Convect
- Enroute Convect

Y-axis: Normalized NAS Wx Index Components (0, 500, 1000, 1500, 2000, 2500)

X-axis: Hour, Z (6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 0, 1, 2, 3, 4, 5)

JFK Traffic Demand vs. Capacity

ATO Dash Board

	Achieve Operational Excellence	Enhance Financial Discipline	Increase Capacity Where Needed	Ensure Viable Future
OWNERS		2.1b - Total labor obligations per flight Actual: $277.10 Target: --		
CUSTOMERS	1.2a - FAA On-Time NAS Arrivals (OEP35)(FP) Actual: 85.98% Target: 87.67%			4.2a - Scheduled blocktime index Actual: 100.54 Target: 100.00
PROCESS	1.3a - Operational Error Category A&B Rate (FP) Actual: 3.80 Target: 4.27 1.3b Runway Incursion Category A&B Rate (FP) Actual: 0.202 Target: 0.530 1.4a - System Airport Efficiency Rate (SAER)(OEP35) Actual: 95.60 Target: 95.25 1.6a - Adjusted operational availability (OEP35)(FP) Actual: 99.82% Target: 99.70% 1.5a -SAER During Moderate & Severe Weather Actual: 90.43 Target: 88.00 1.6b - NAS equipment delay rate Actual: 2.99 Target: 1.75	2.5b - Annualized flights per ATO direct employee Actual: 752 Target: 769 2.4c - ATO labor obligations overhead Actual: 17.9% Target: 25.0% 2.4e - ATO Direct:Indirect Field Employee Ratio Actual: 10.52 Target: 10.08 2.6a - Acquisition programs within projected baseline at completion Actual: 86.0% Target: 76.0% 2.6b - Critical acquisition investments F&E cost & schedule (FP) Actual: 100 Target: 87.5	3.3b - Avg Daily Airport Capacity (OEP35)(FP) Actual: 101,786 Target: 101,562 3.3c - Avg Daily Airport Capacity (7 Metro)(FP) Actual: 61,801 Target: 63,080	
EMPLOYEES	1.9a - Improvement in top management communications Actual: -- Target: --	2.7a - Air Traffic Controller hiring (FP) Actual: 14,512 Target: 14,664		

NAS On-time Comparison

- **Time Period October-July**   FY05   FY06   FY07YTD

- **With NY Metro Included ALL OEP 35**   **88.18**   **88.42**   **86.29**

- **Without NY Metro (LGA, JFK, EWR)**   **88.90**   **89.51**   **87.68**
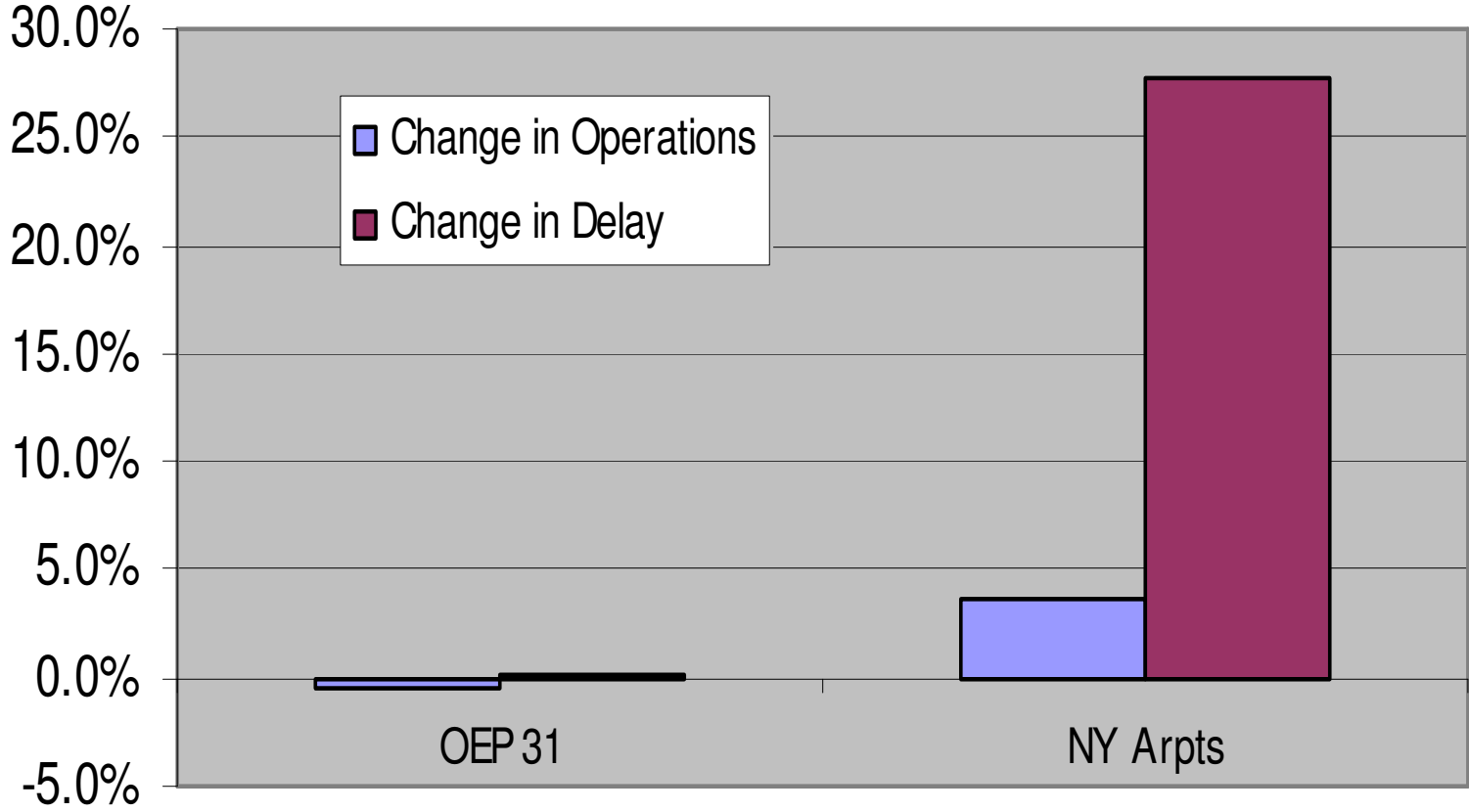
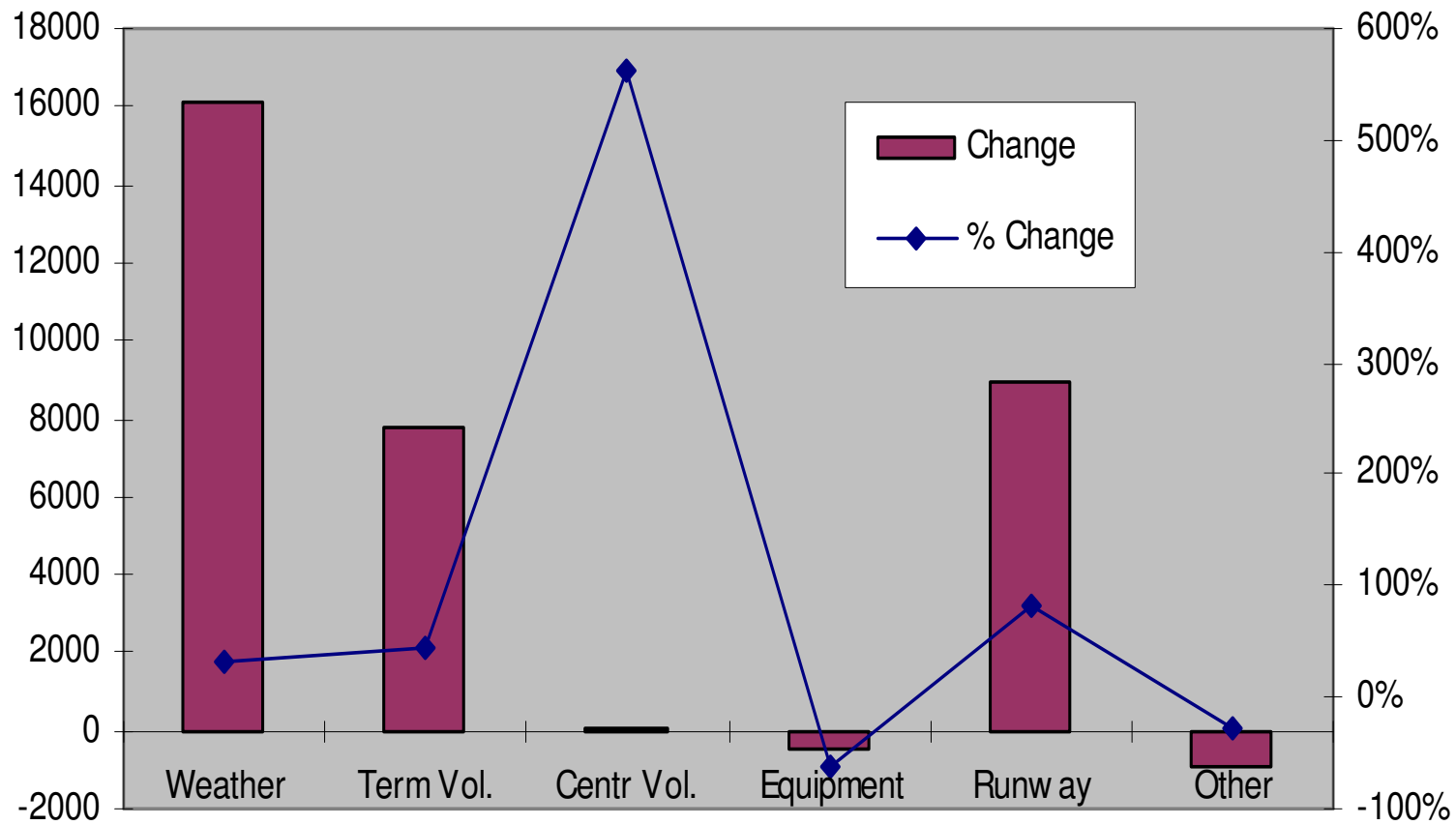# NAS On Time Causal Comparison Analysis

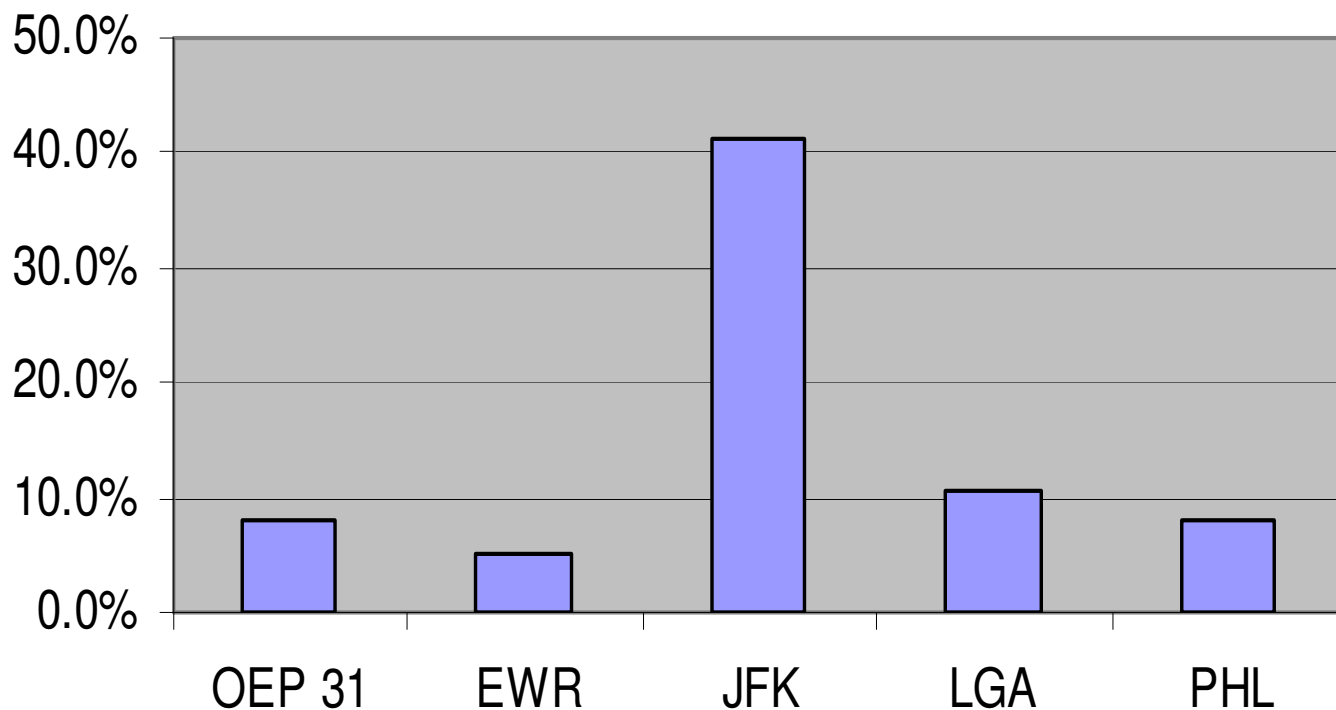**NAS On time Causality Comparison**
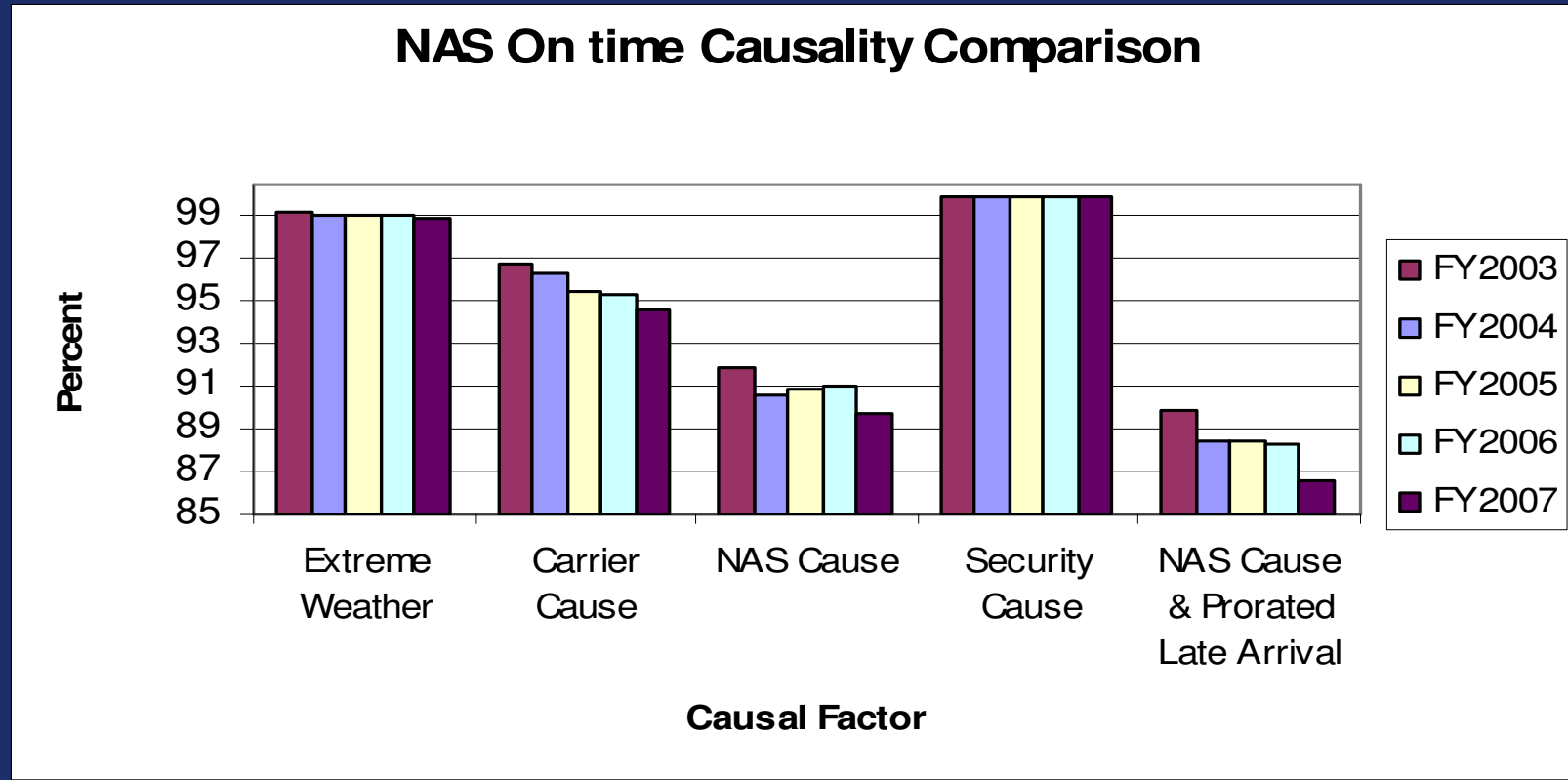
NY OPSNET Percent of OEP 35 Totals
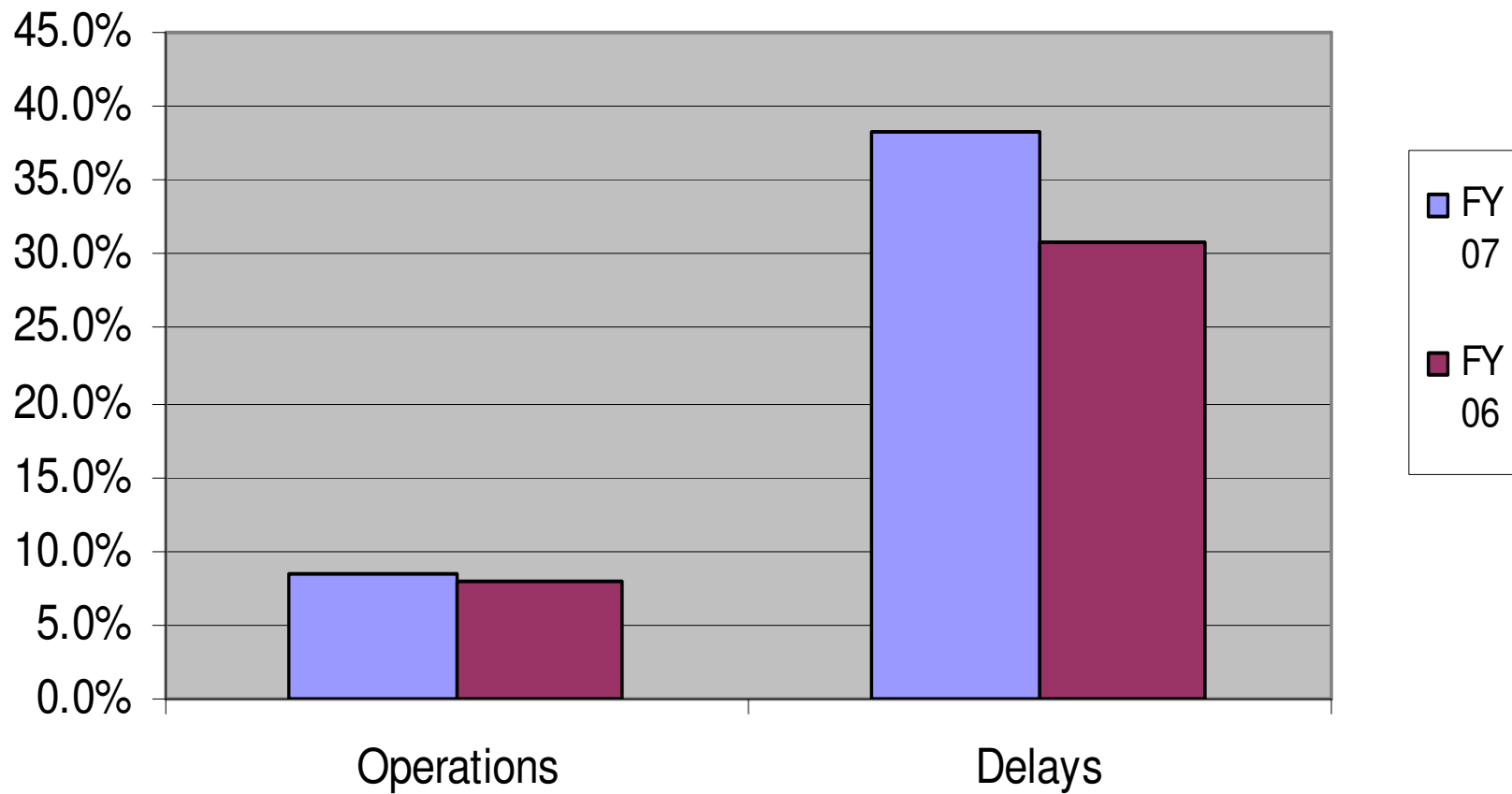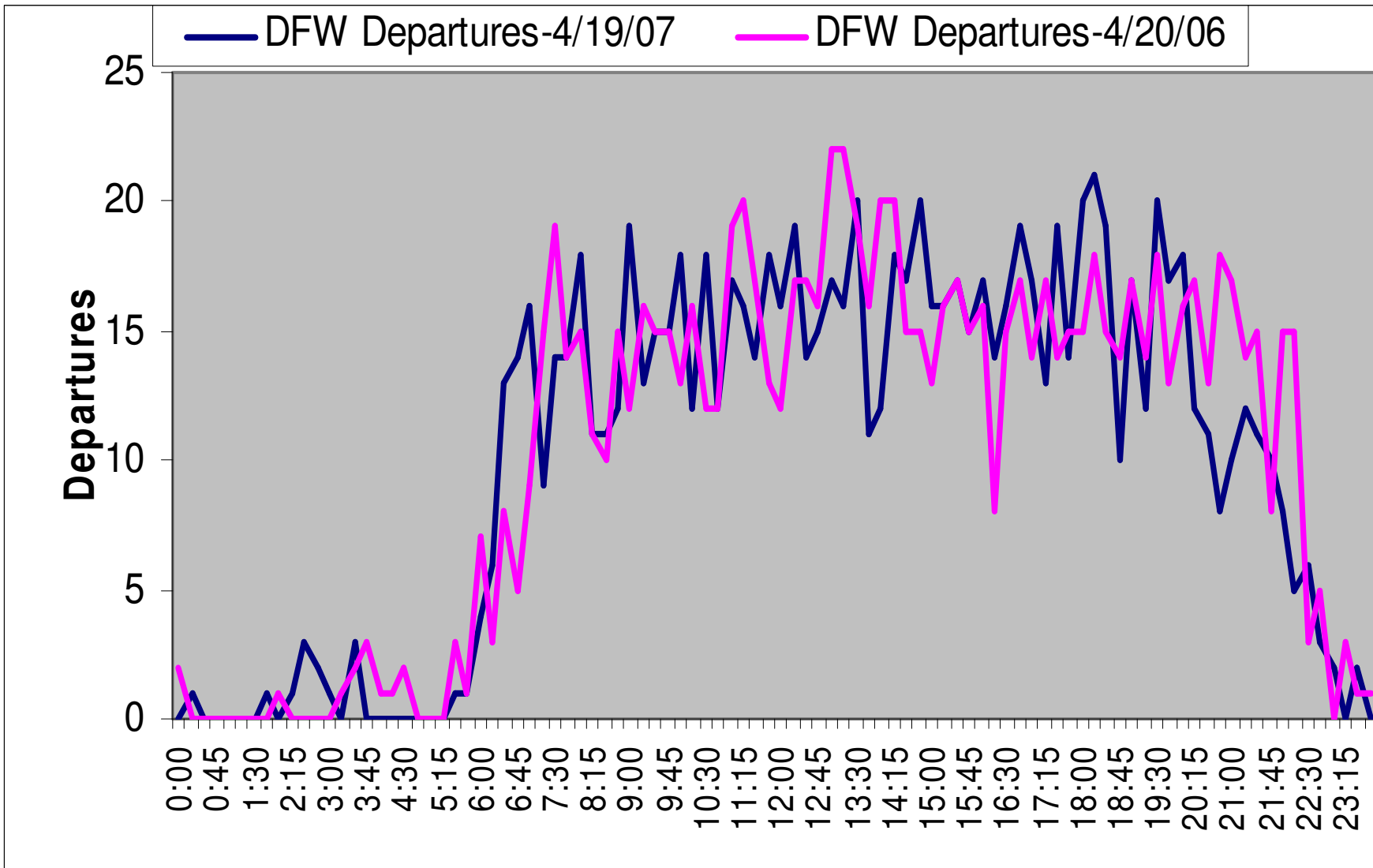
OPSNET Change FY06 to FY07
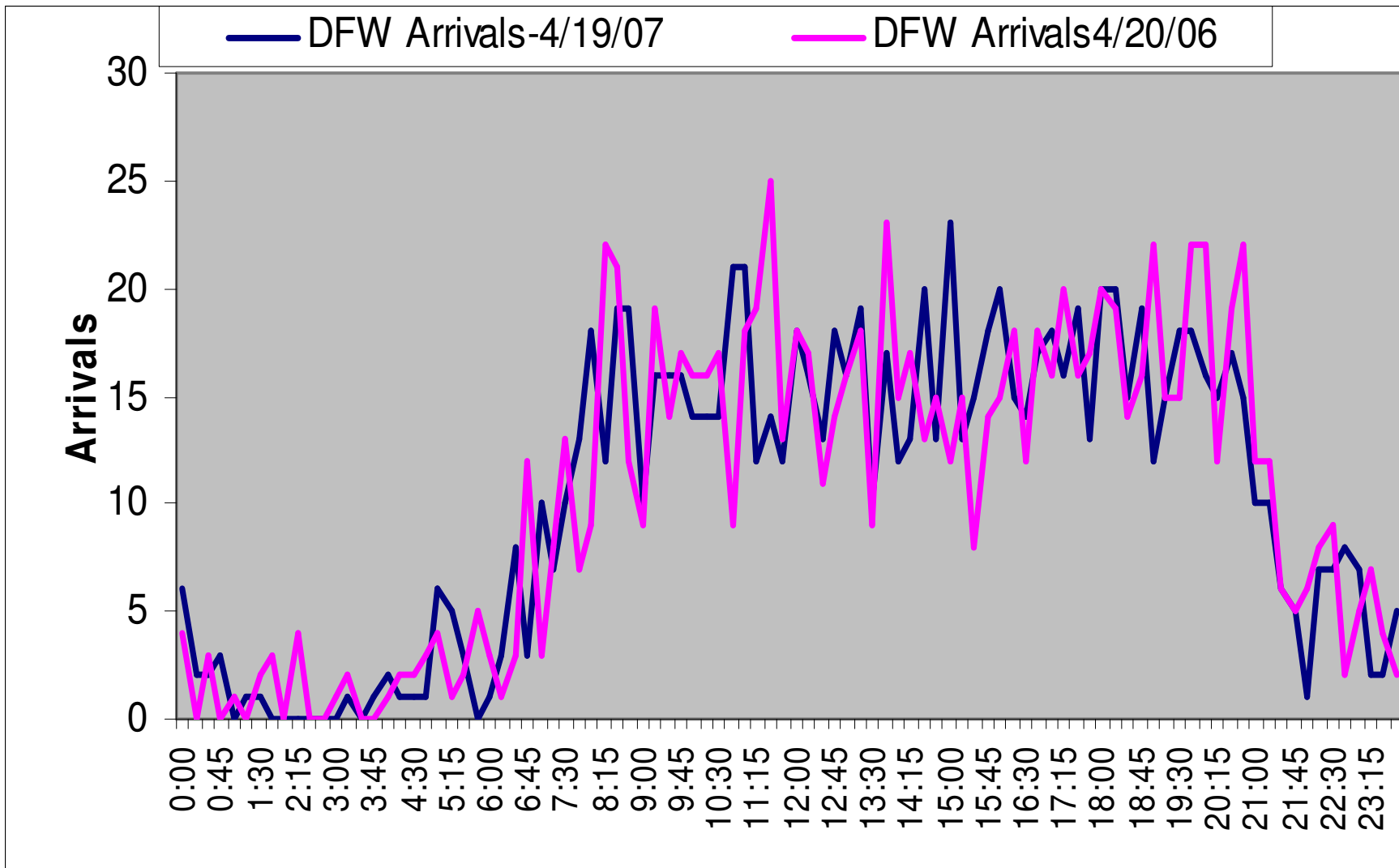
OPSNET Change in Delays By Cause FY06-FY07

Change in Delay FY06 to FY07 (Gate, Taxi-out, Airborn, Taxi in)

Departures

Legend: DFW Departures-4/19/07 (navy), DFW Departures-4/20/06 (magenta)

Airline 5 Performance
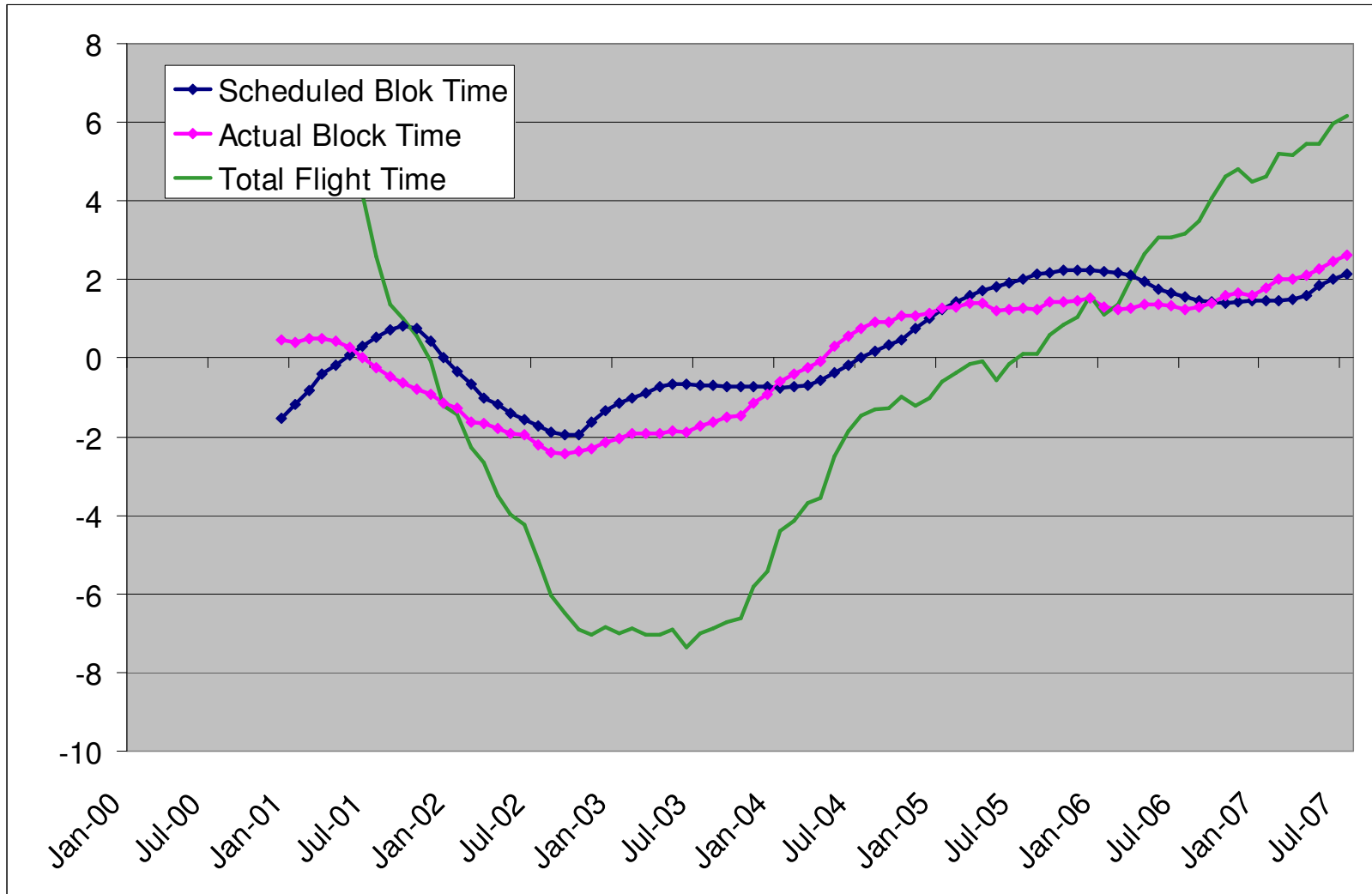
Performance Measures: Primary Data Sources

- ASPM
- ASQP
- ETMS
- OPSNET
- PDARS
- OAG
- NCDC/NWS

E-WITI, 2-hr, 4-hr & 6-hr WITI-FA (Experimental) Period Ending 08/20/2007

En-Route WITI (NCWD) and E-WITI-FA from CCFP, Last 30 Days
Absolute (not normalized) values

Legend:
- E-WITI
- 2-hr E-WITI-FA
- 4-hr E-WITI-FA
- 6-hr E-WITI-FA

Y-axis: Raw WITI
X-axis: Date
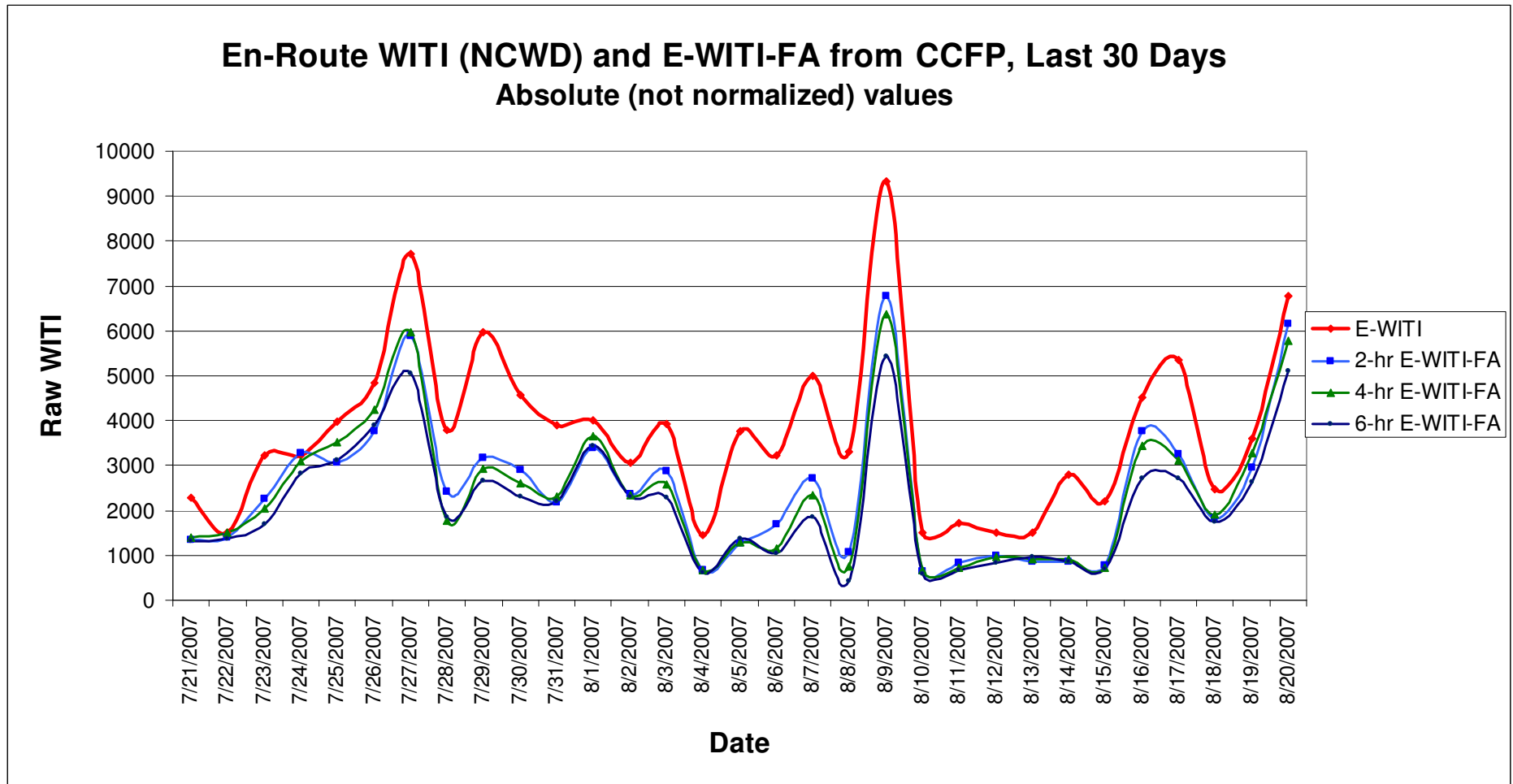
NAS Delay Trends

- Where is Delay Growing
  - Phase of Flight
  - Facility (OEP, Center)
- What is driving delay?
  - Traffic?
    - Demand Growth?
    - Scheduling?
  - Weather?
  - Construction?
  - Regulations?
  - Fleet Mix?
  - ATC?

Delay Comparison (2004 thru 2007) Versus Unimpeded
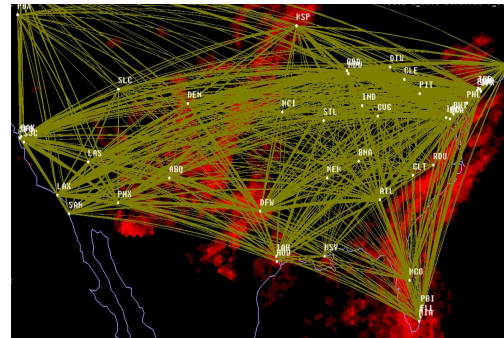
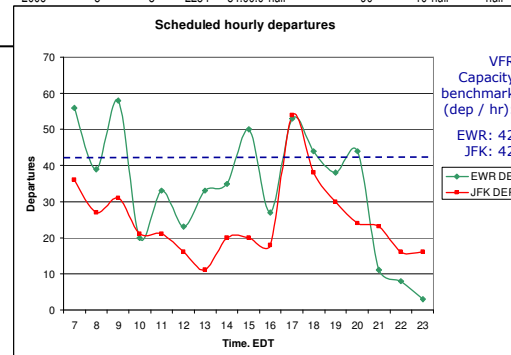# Weather / Traffic Index

Weighted sum of 3 components:

– **En-route Weather Index** reflecting impact of convective weather on 39 major airports

- Linear impact (more Wx, more traffic = proportionally higher impact)

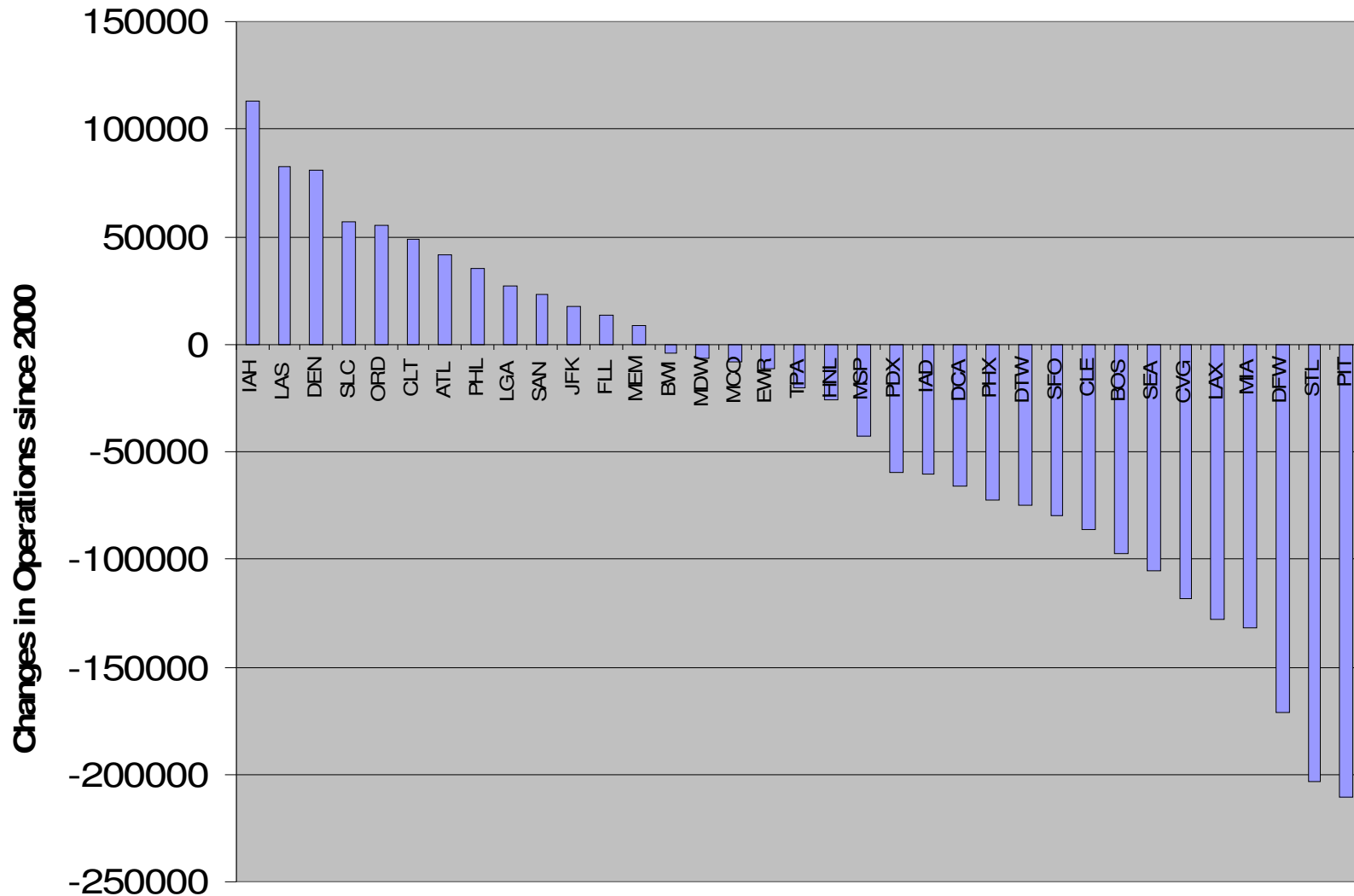– **Terminal Index** for same airports: local Wx impact

- Linear impact

– **Queuing Index** for same airports reflecting excess traffic demand vs. capacity

- May be exacerbated by reduced capacity due to local Wx and en-route Wx
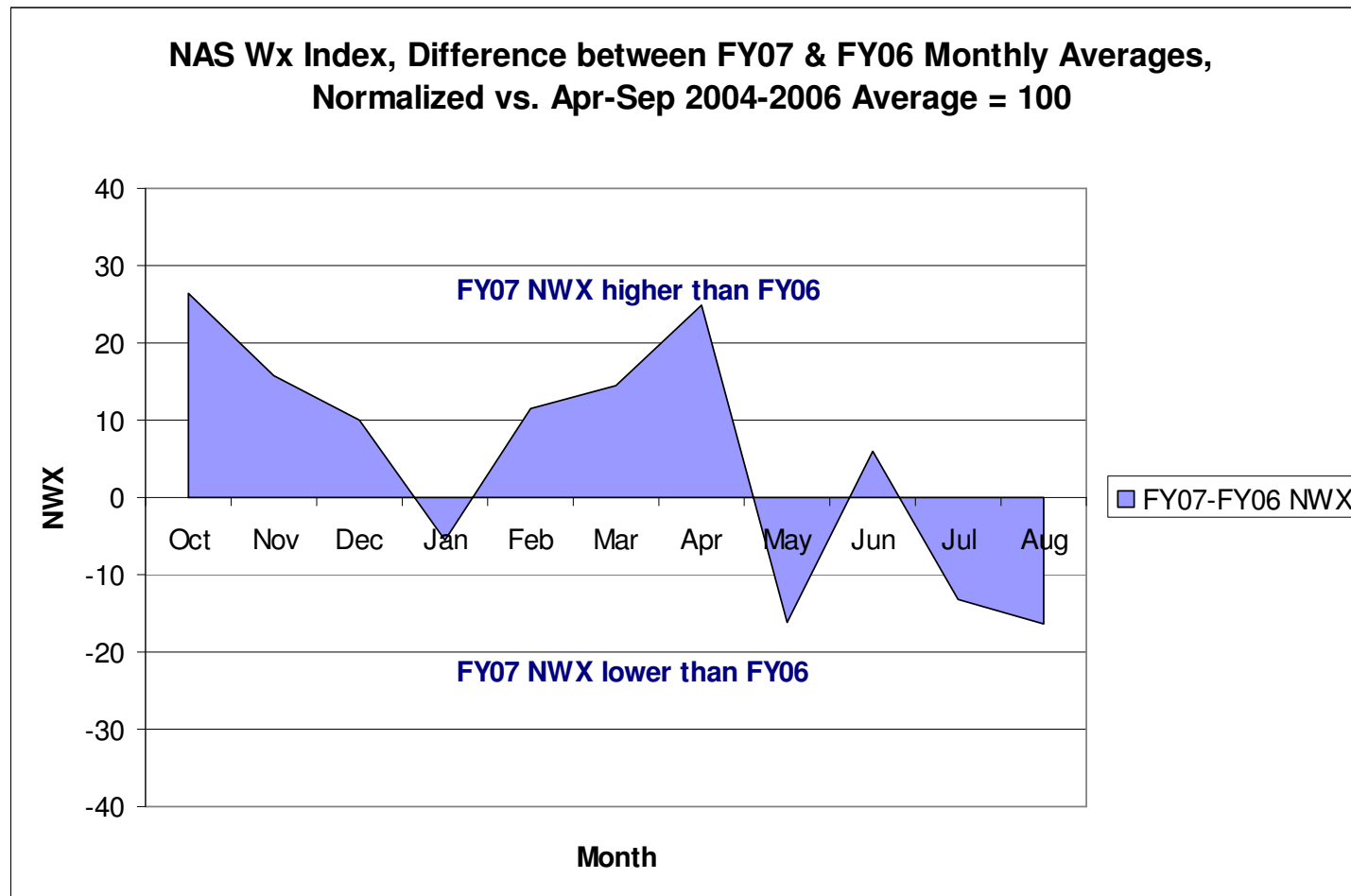- Non-linear (exponential) impact

KPHL	2006	5	8	1654	54:00.0 null	75	10 null	null	10	17	1 null	8	14	34	70	15
KPHL	2006	5	8	1754	54:00.0 null	100	10 null	null	10	17	1 null	8	14	34	80	14
KPHL	2006	5	8	1754	54:00.0 null	100	10 null	null	10	17	1 null	8	14	34	80	14
KPHL	2006	5	8	1854	54:00.0 null	80	10 null	null	10	17	1 null	8	14	34	80	13
KPHL	2006	5	8	1954	54:00.0 null	80	10 null	null	10	16	1 null	7	13	36	60	10
KPHL	2006	5	8	2054	54:00.0 null	85	10 null	null	10	16	-1 null	7	13	31	60	10
KPHL	2006	5	8	2054	54:00.0 null	85	10 null	null	10	16	-1 null	7	13	31	60	10
KPHL	2006	5	8	2154	54:00.0 null	85	10 null	null	10	16	-2 null	7	13	29	60	10
KPHL	2006	5	8	2254	54:00.0 null	90	10 null	null	10	14	-3	9	12	31	70	9
KPHL									10	14	-3	9	5	12	31	70	9
KPHL									10	14	-3	8	5	12	31	80	11

METAR

Scheduled hourly departures

VFR Capacity benchmark (dep / hr):

EWR: 42
JFK: 42

Uneven Growth: Operations 2000 vs. 2006

[FY07 – FY06] Weather Has Been Worse

NAS Wx Index, Difference between FY07 & FY06 Monthly Averages, Normalized vs. Apr-Sep 2004-2006 Average = 100

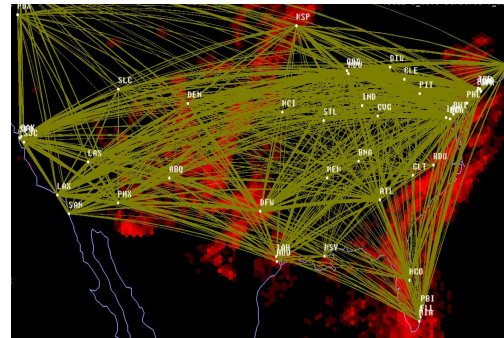August 2007 is month-to-date as at 08/20

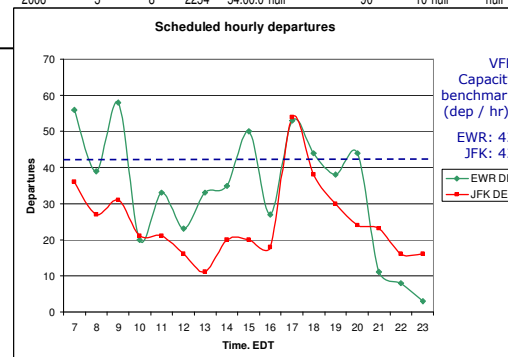# Weather / Traffic Index

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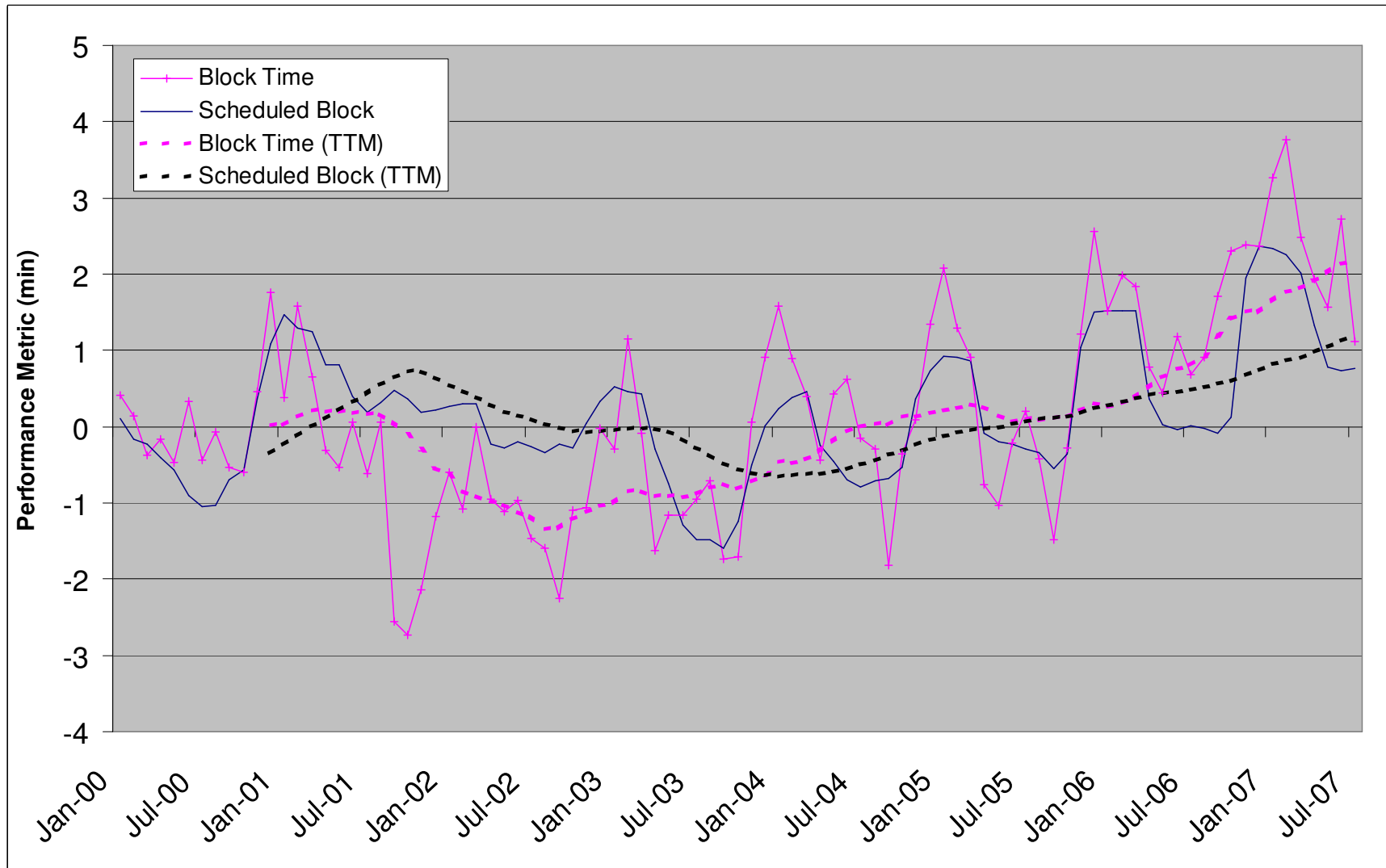- Non-linear (exponential) impact

KPHL	2006	5	8	1654	54:00.0 null		75	10 null	null		10	17	1 null		8	14	34	70	15
KPHL	2006	5	8	1754	54:00.0 null		100	10 null	null		10	17	1 null		8	14	34	80	14
KPHL	2006	5	8	1754	54:00.0 null		100	10 null	null		10	17	1 null		8	14	34	80	14
KPHL	2006	5	8	1854	54:00.0 null		80	10 null	null		10	17	1 null		8	14	34	80	13
KPHL	2006	5	8	1954	54:00.0 null		80	10 null	null		10	16	1 null		7	13	36	60	10
KPHL	2006	5	8	2054	54:00.0 null		85	10 null	null		10	16	-1 null		7	13	31	60	10
KPHL	2006	5	8	2054	54:00.0 null		85	10 null	null		10	16	-1 null		7	13	31	60	10
KPHL	2006	5	8	2154	54:00.0 null		85	10 null	null		10	16	-2 null		7	13	29	60	10
KPHL	2006	5	8	2254	54:00.0 null		90	10 null	null		10	14	-3		9	5	12	31	70	9
KPHL											10	14	-3		9	5	12	31	70	9
KPHL											10	14	-3		8	5	12	31	80	11

METAR

Scheduled hourly departures

VFR Capacity benchmark (dep / hr):
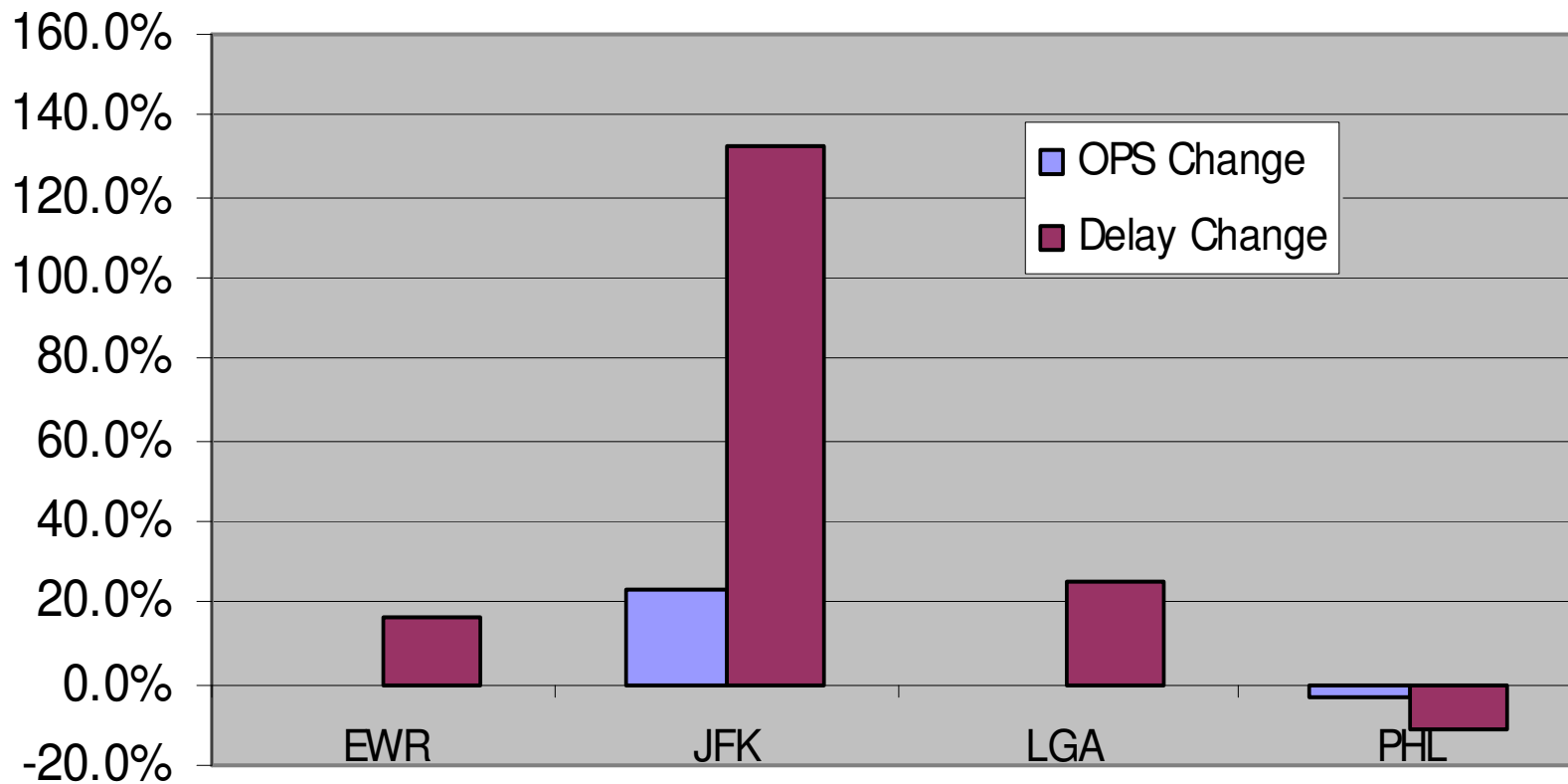EWR: 42
JFK: 42

EWR DEP
JFK DEP

Performance Metric Block Time

NY Area OPSNET Change FY06 to FY 07

Some NAS Delay Trends

NAS and NY (EWR,LGA,JFK) ASPM Delay
Trendlines: 4-order polynomial

NAS and NY ASPM Delay, Monthly Averages + Trendlines, Jan 2004 - Jul 2007
Normalized vs. OEP-35 Apr-Sep 2004-2006 Average (=100)

Legend:
- NAS Delay
- NY Delay
- Poly. (NAS Delay)
- Poly. (NY Delay)

X-axis: Month
Y-axis: Normalized Delay

Years: 2004, 2005, 2006, 2007