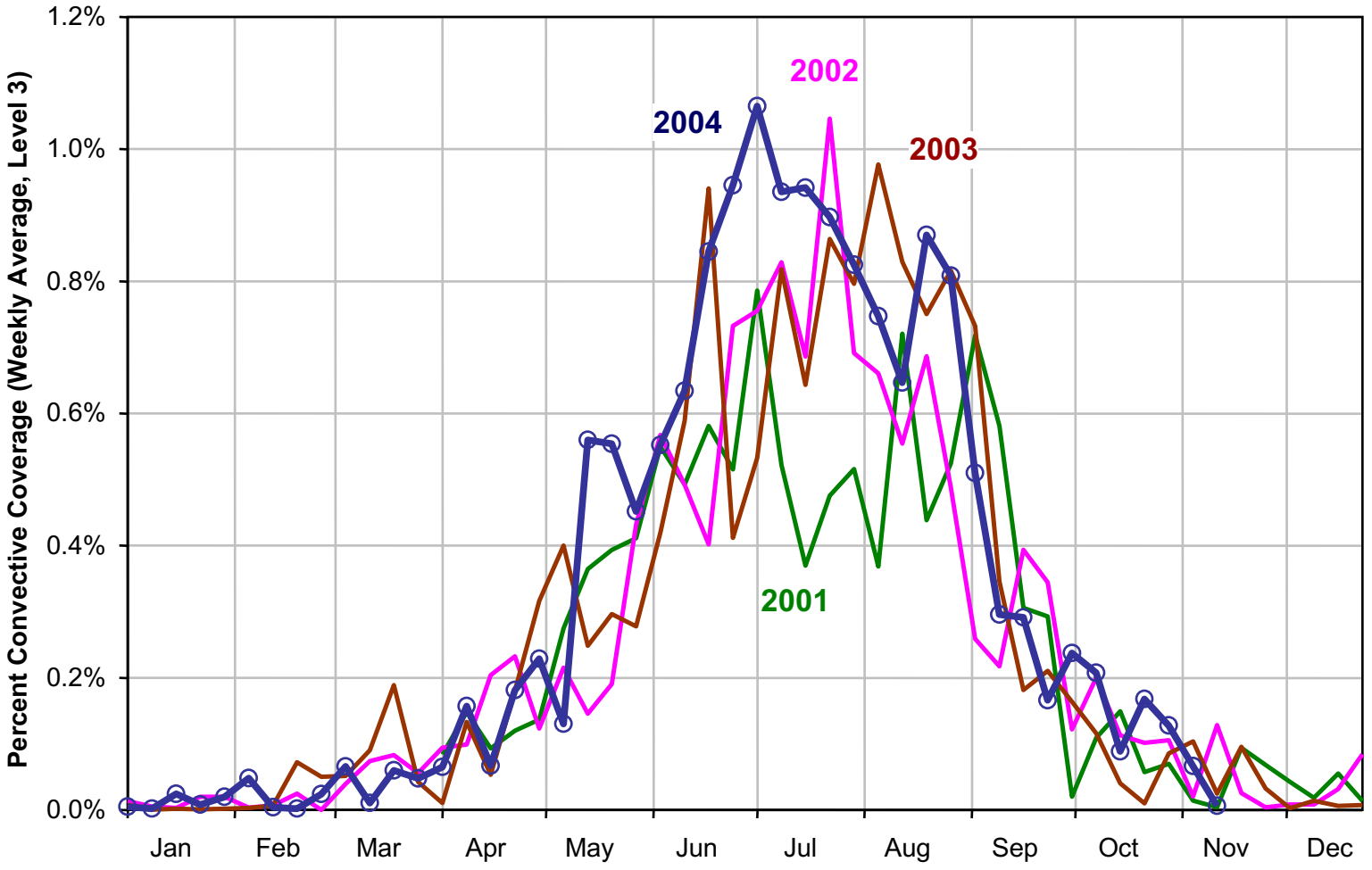
CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

System Performance and Convective Weather

Kenneth Lamon, Ph.D.

15 March 2006

June, July and August are the Peak of the Convective Weather Season



Source: NOAA, FSL; measures the average area of thunderstorms over the US at 19Z, 21Z, and 23Z , weekly average

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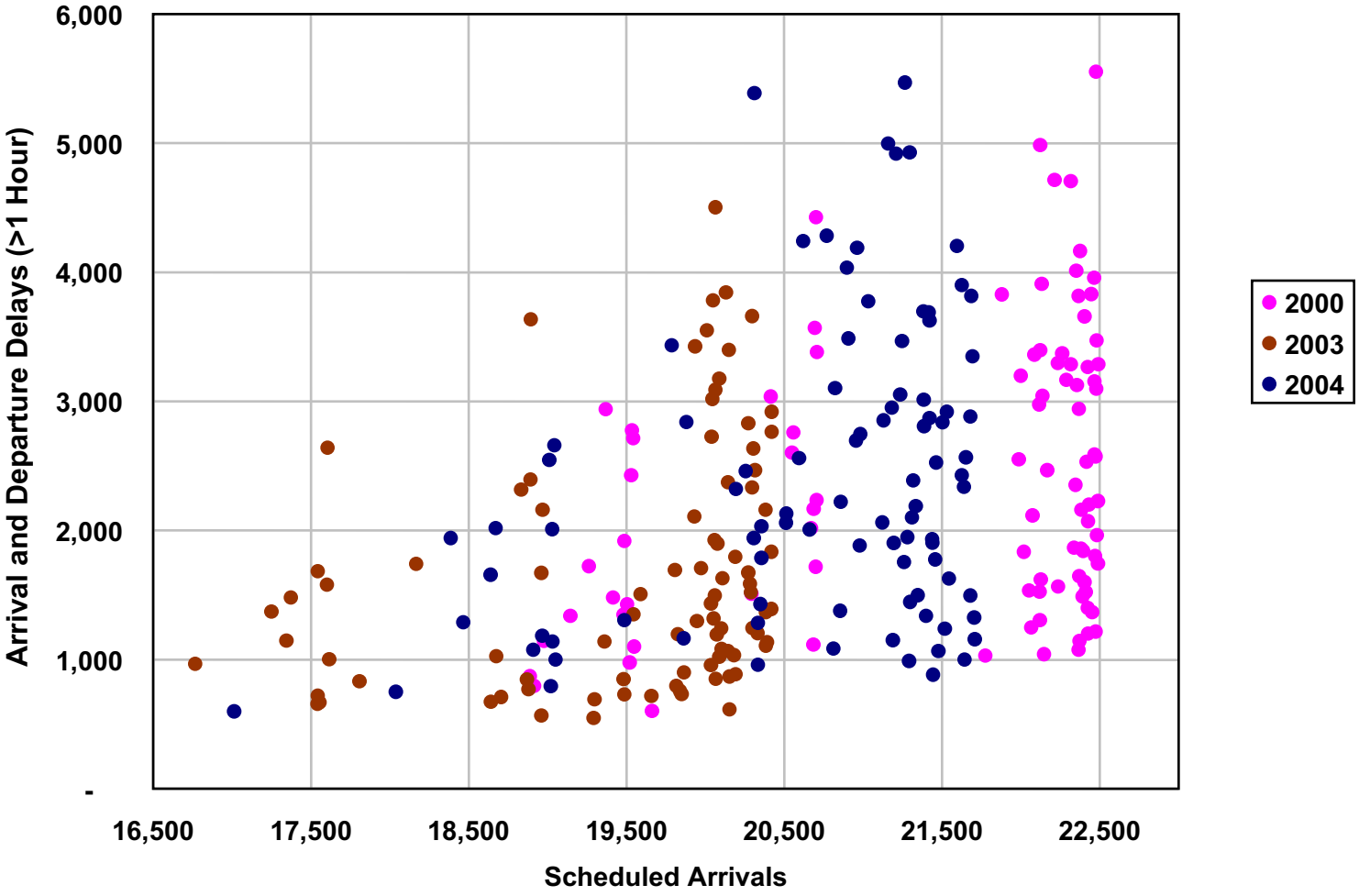
Delays = 500 + a*Weather*(Schedule - 16,500)



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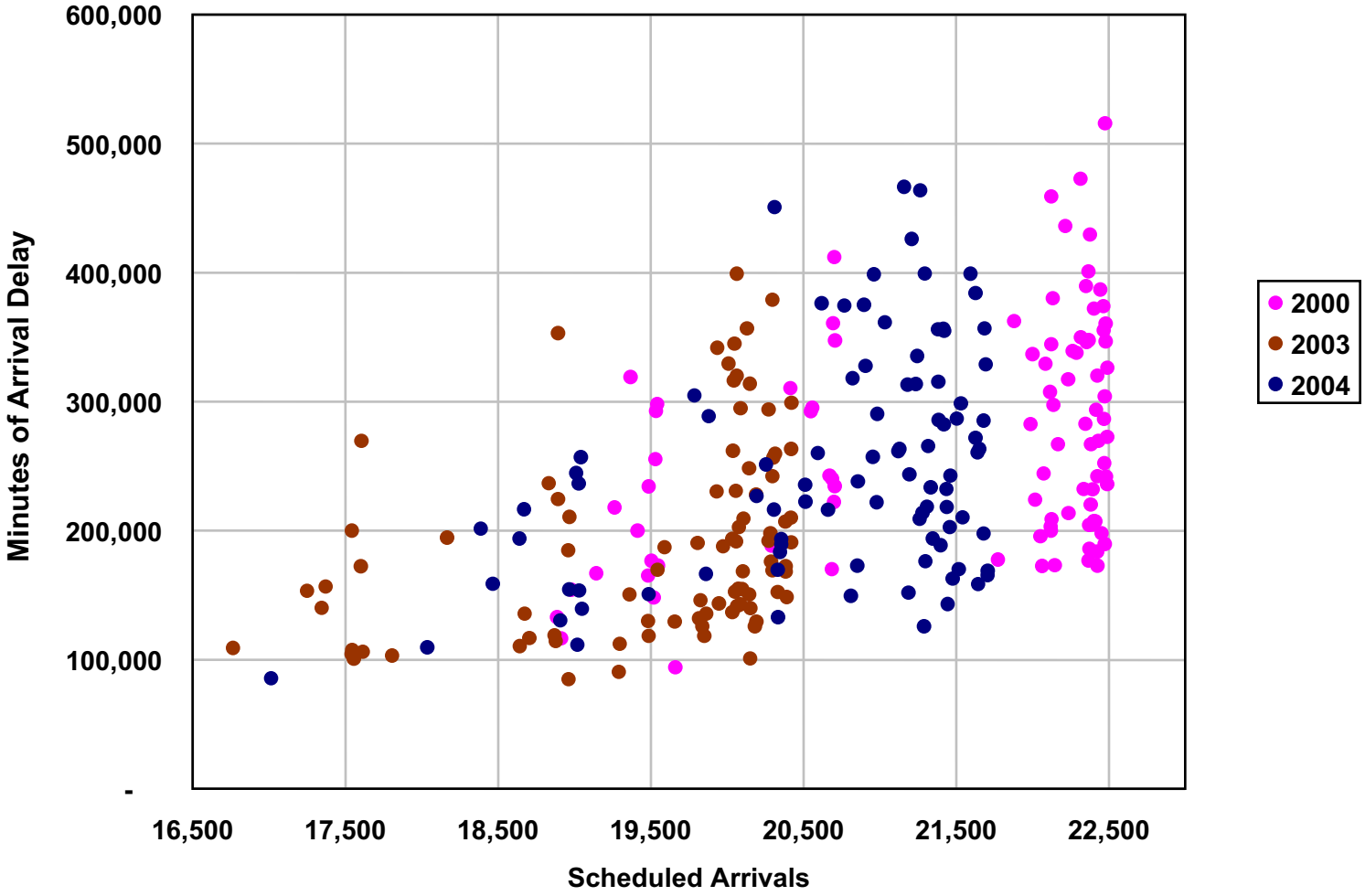
$$\text{Minutes} = 100{,}000 + b * \text{Weather} * (\text{Schedule} - 16{,}500)$$



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An Airport-specific Convective Weather Metric

- Take an airport's maximum storm intensity each hour
- Multiply by the number of scheduled arrivals that hour
- Sum over all hours of the day
- Sum over 45 airports
- (Divide by total number of scheduled arrivals)

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View the PPT movie here

CAASD

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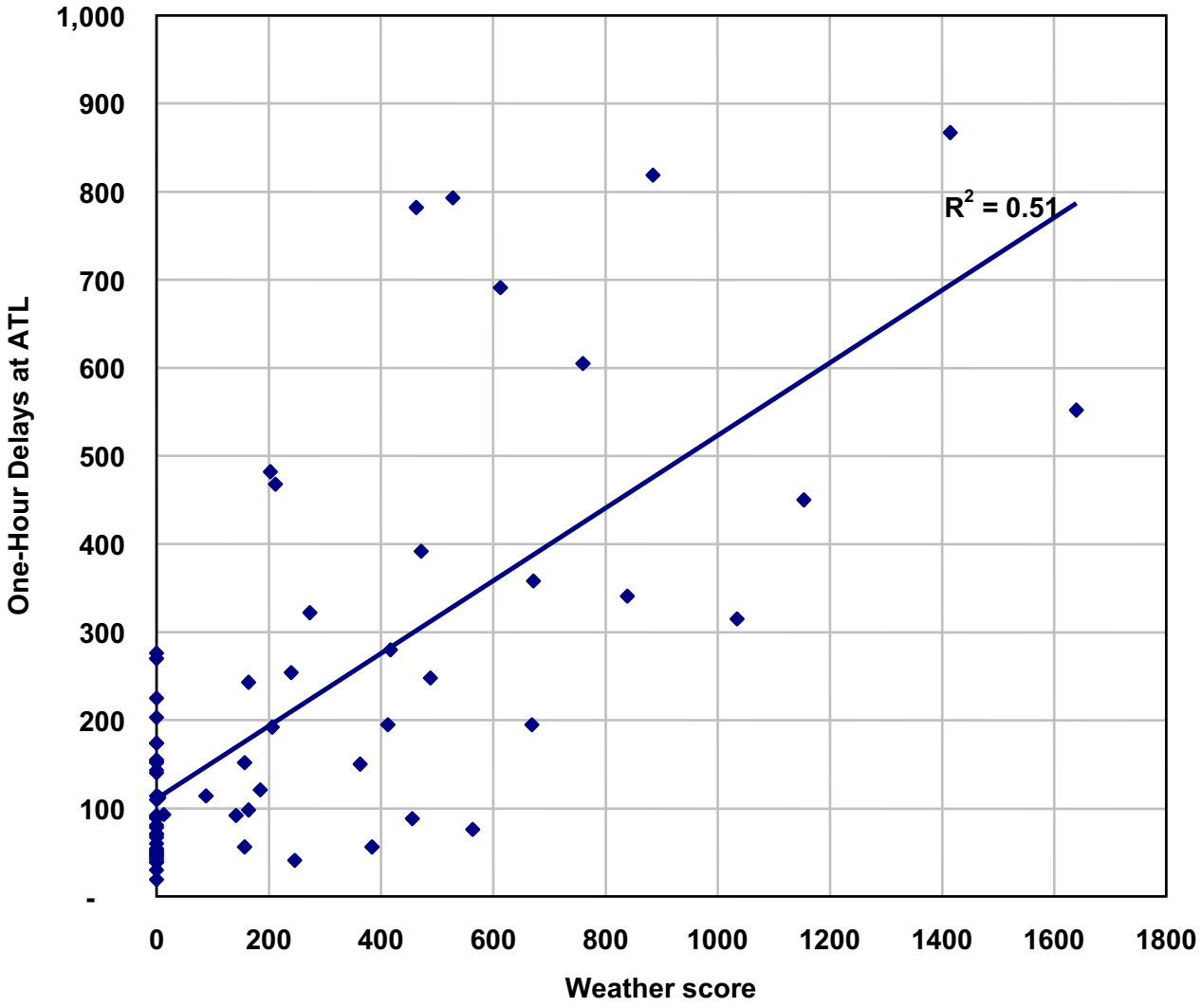
ATL Delays Versus Weather Score



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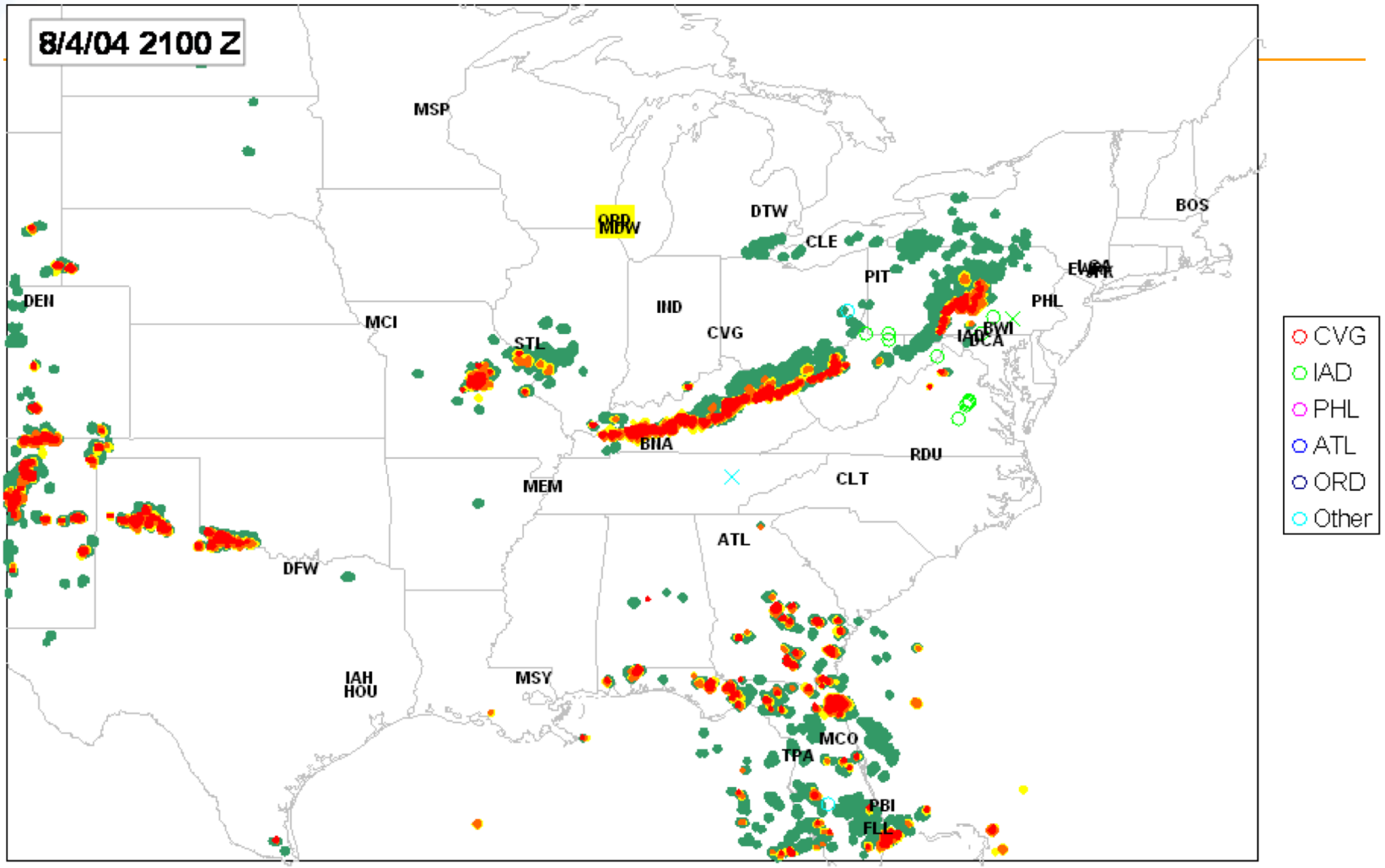
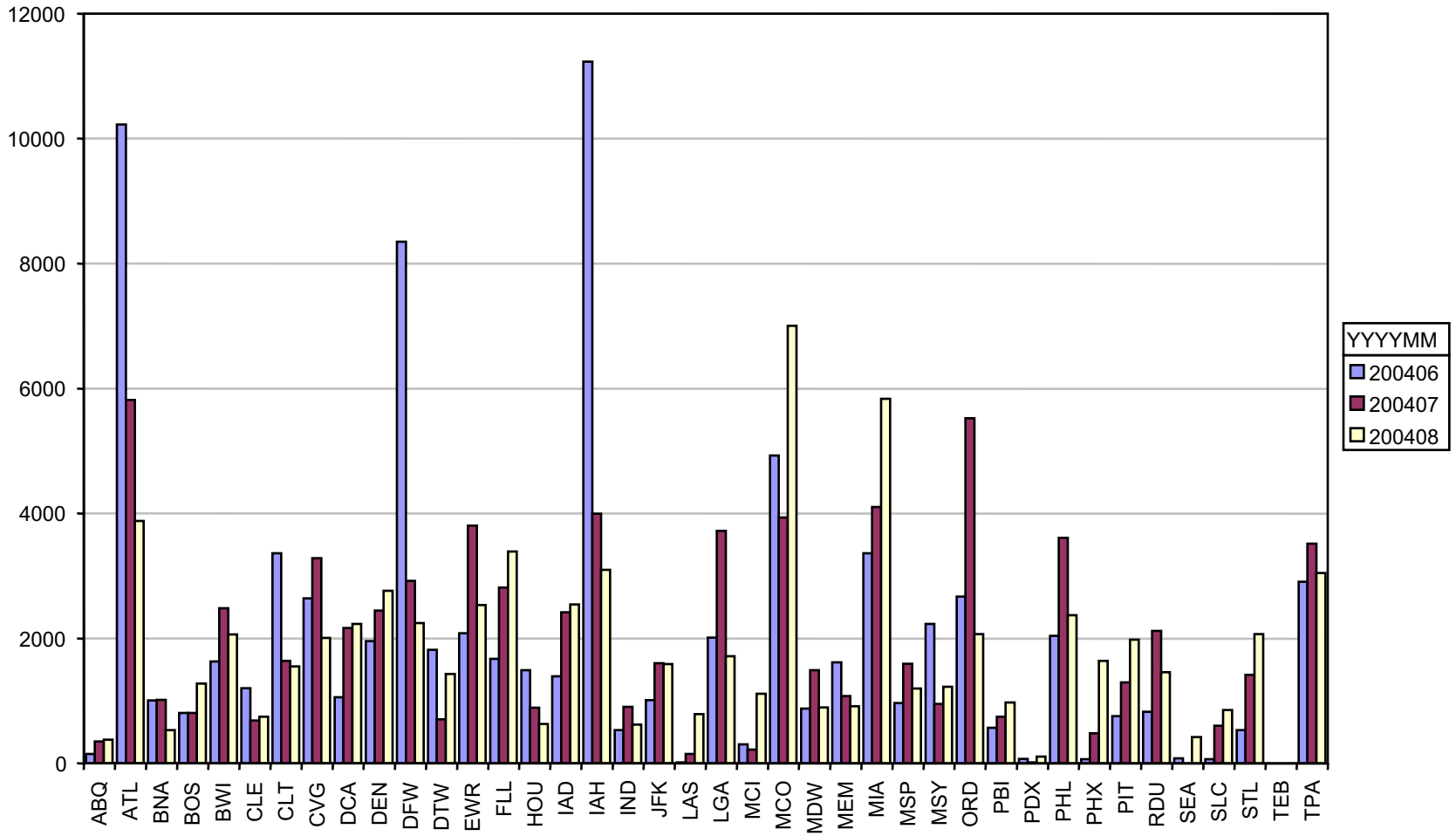


ORD: IMPROVED

Monthly Convective Weather Score by Major Airport



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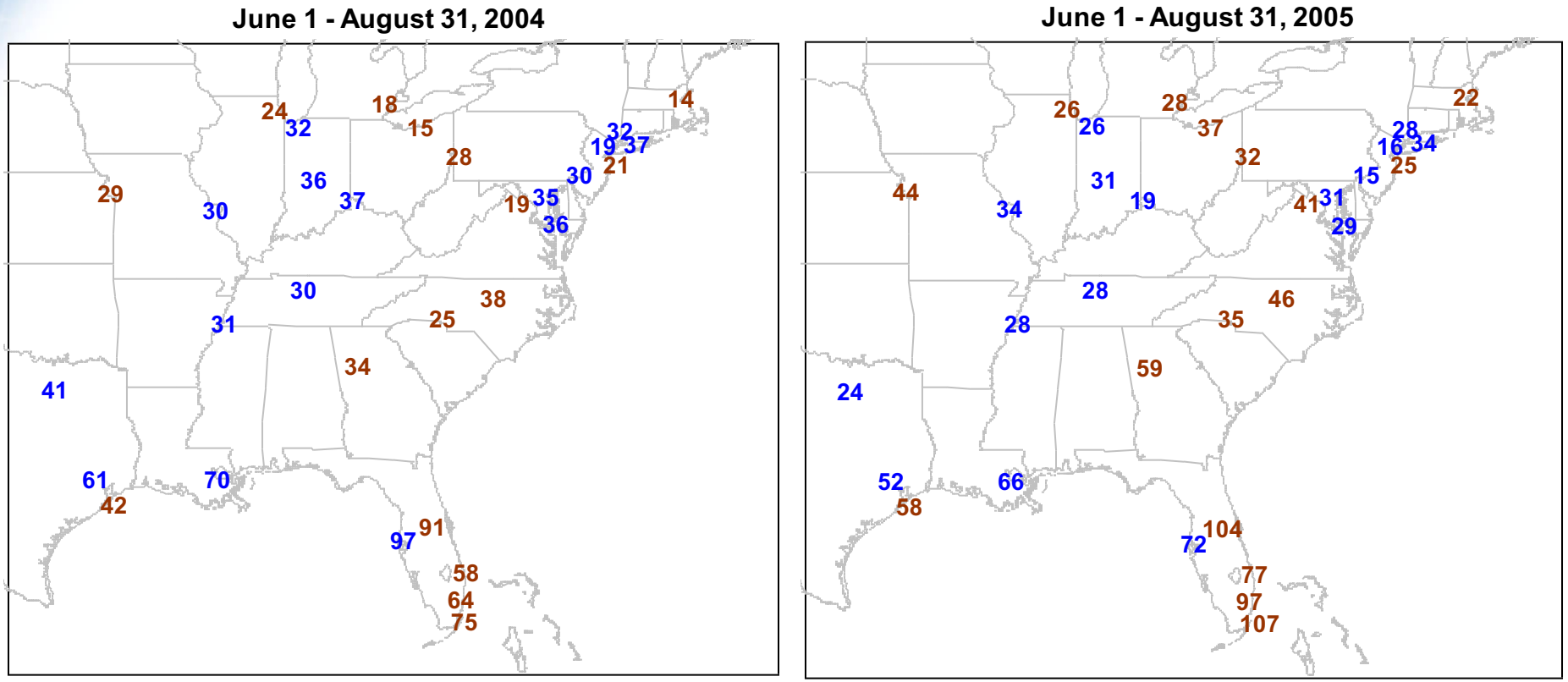
F065-B06-007

Number of Hours Having Thunderstorm Intensity>3



BROWN indicates locations where the frequency of thunderstorms increased from 2004 to 2005

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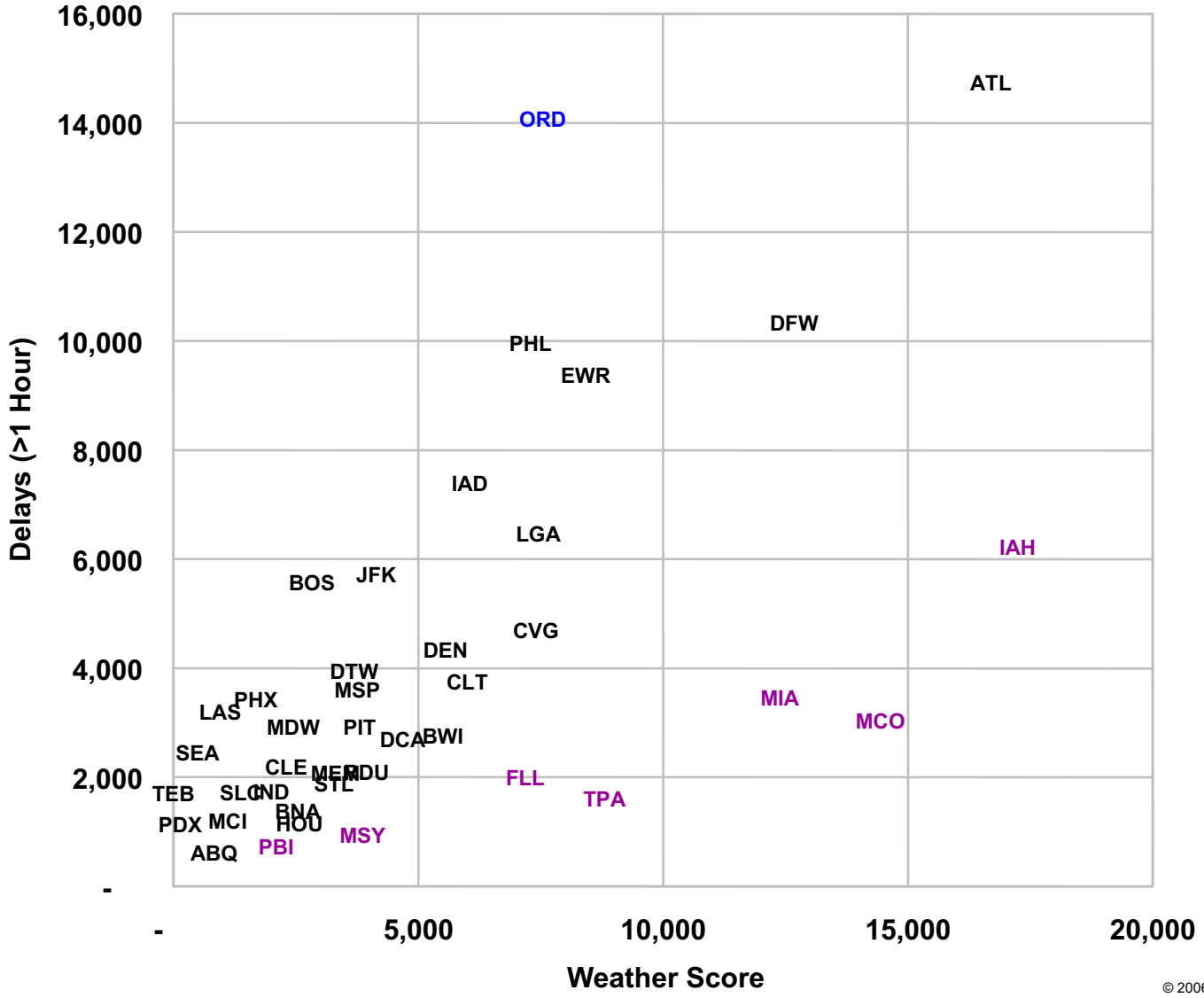
Delay and Convective Weather Score: June – August 2004



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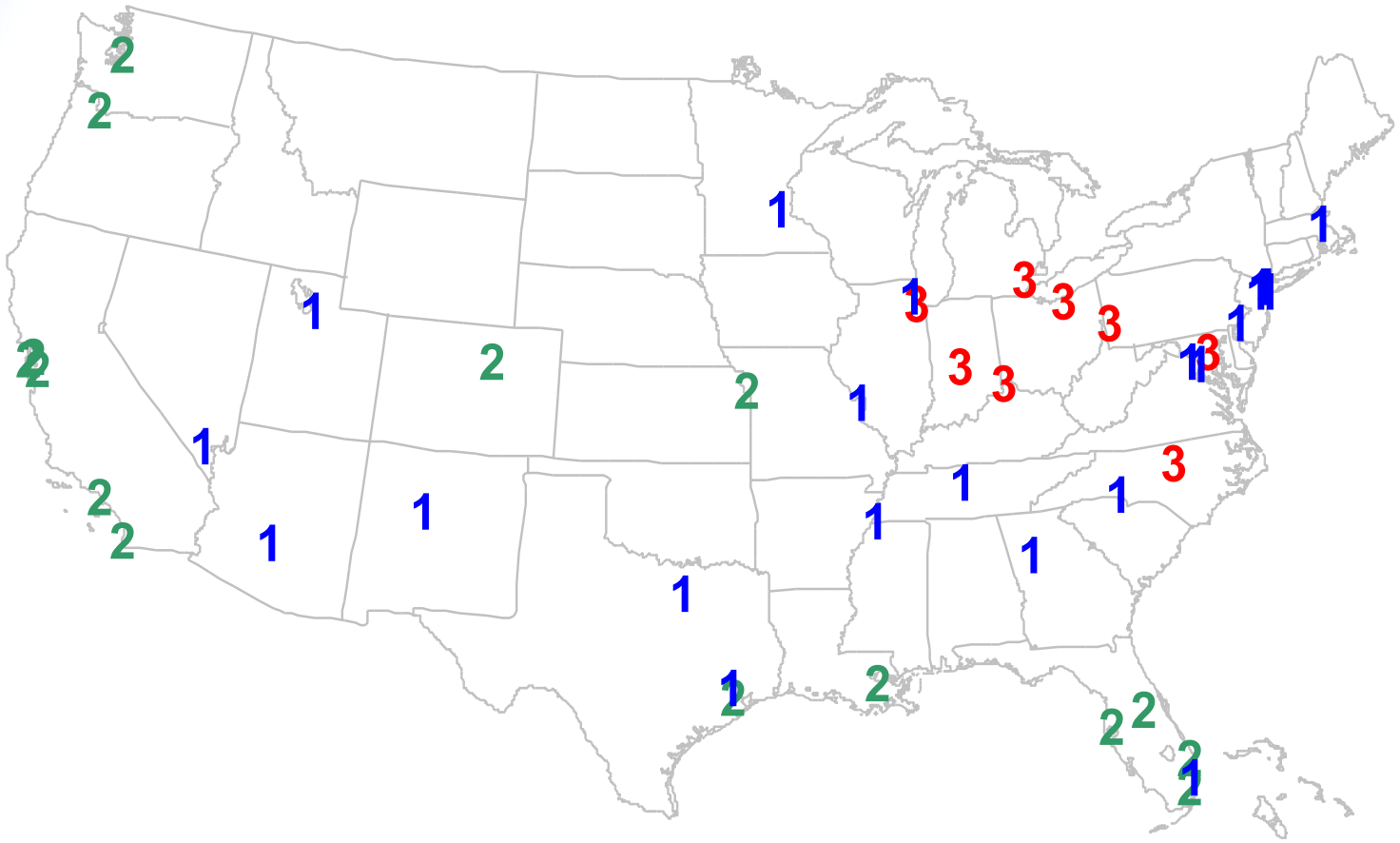
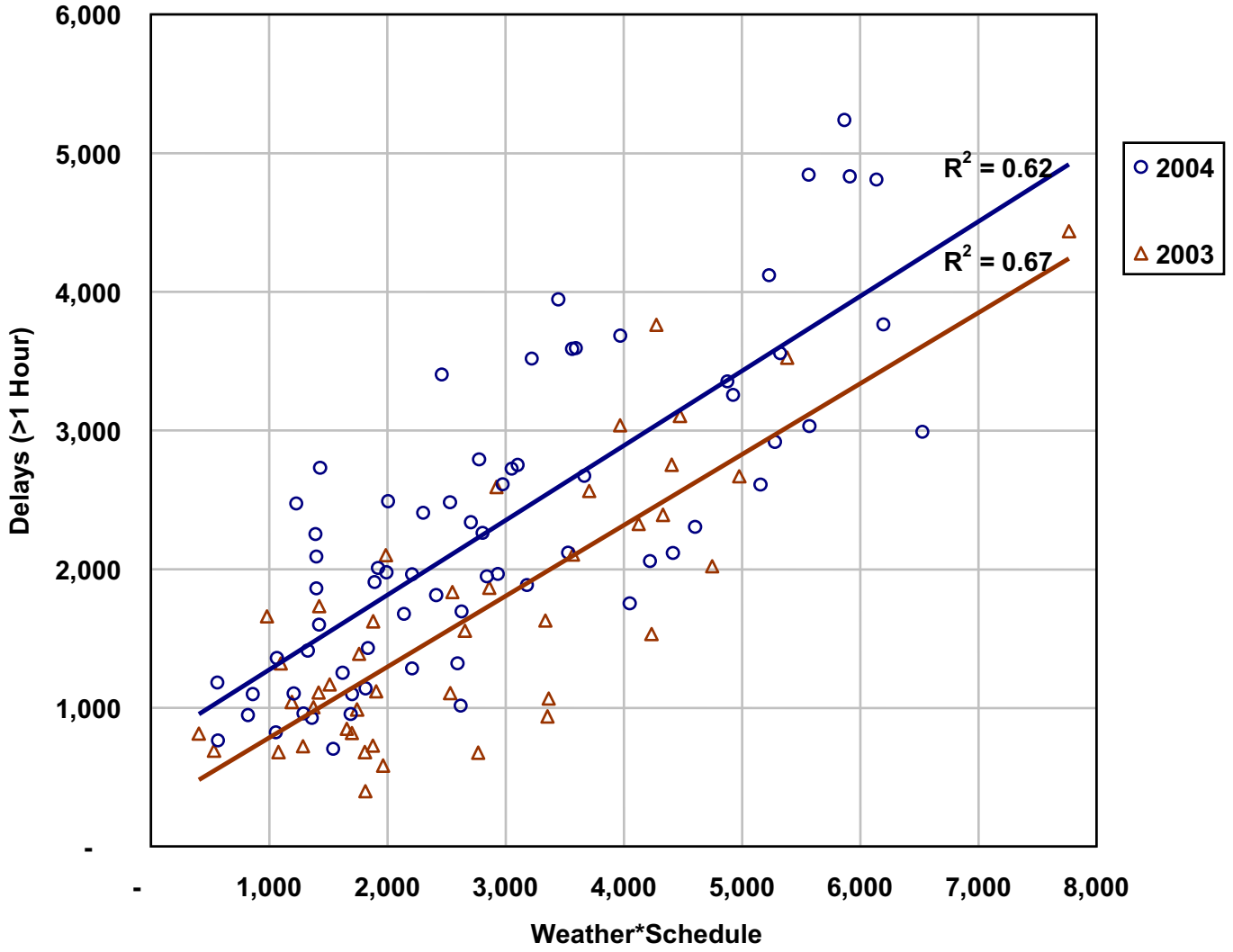
R-Squared Improves (a little) if Airports are Grouped



G1	G2	G3
ABQ	DEN	BWI
ATL	HOU	CLE
BNA	LAX	CVG
BOS	MCI	DTW
CLT	MCO	IND
DCA	MIA	MDW
DFW	MSY	PIT
EWR	OAK	RDU
FLL	PBI	
IAD	PDX	
IAH	SAN	
JFK	SEA	
LAS	SFO	
LGA	SJC	
MEM	TPA	
MSP		
ORD		
PHL		
PHX		
SLC		
STL		
TEB		

Delays Versus Weather Score: 45 Airports



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Regression Results 2003 and 2004

Delays = 507 + 1.8*Weather*(Schedule - 15,429)
+ 298*Year2004

R-squared = 0.65

Minutes = 106,000 + 174*Weather*(Schedule - 16,870)
+ 24,454*Year2004

R-squared = 0.67

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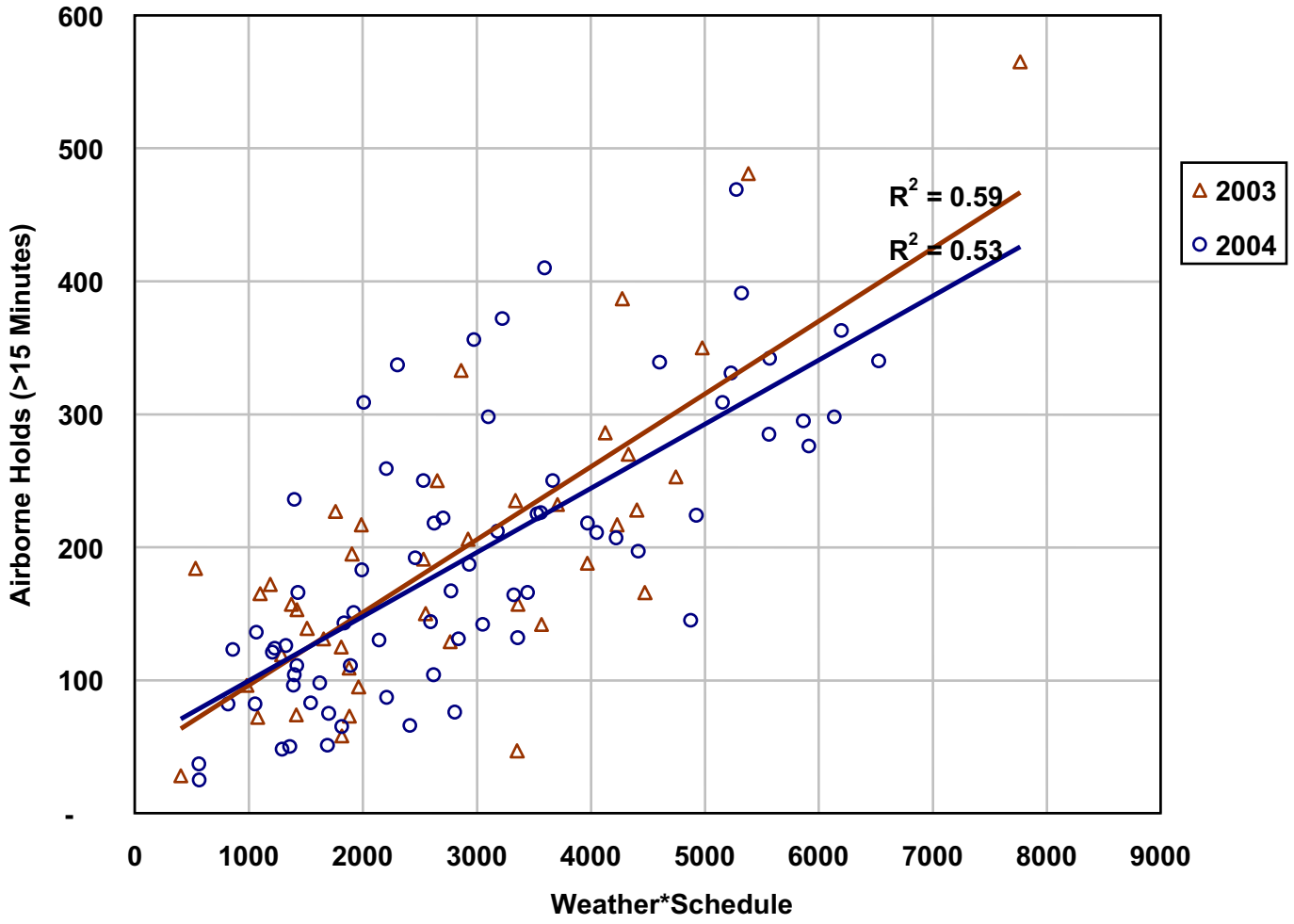
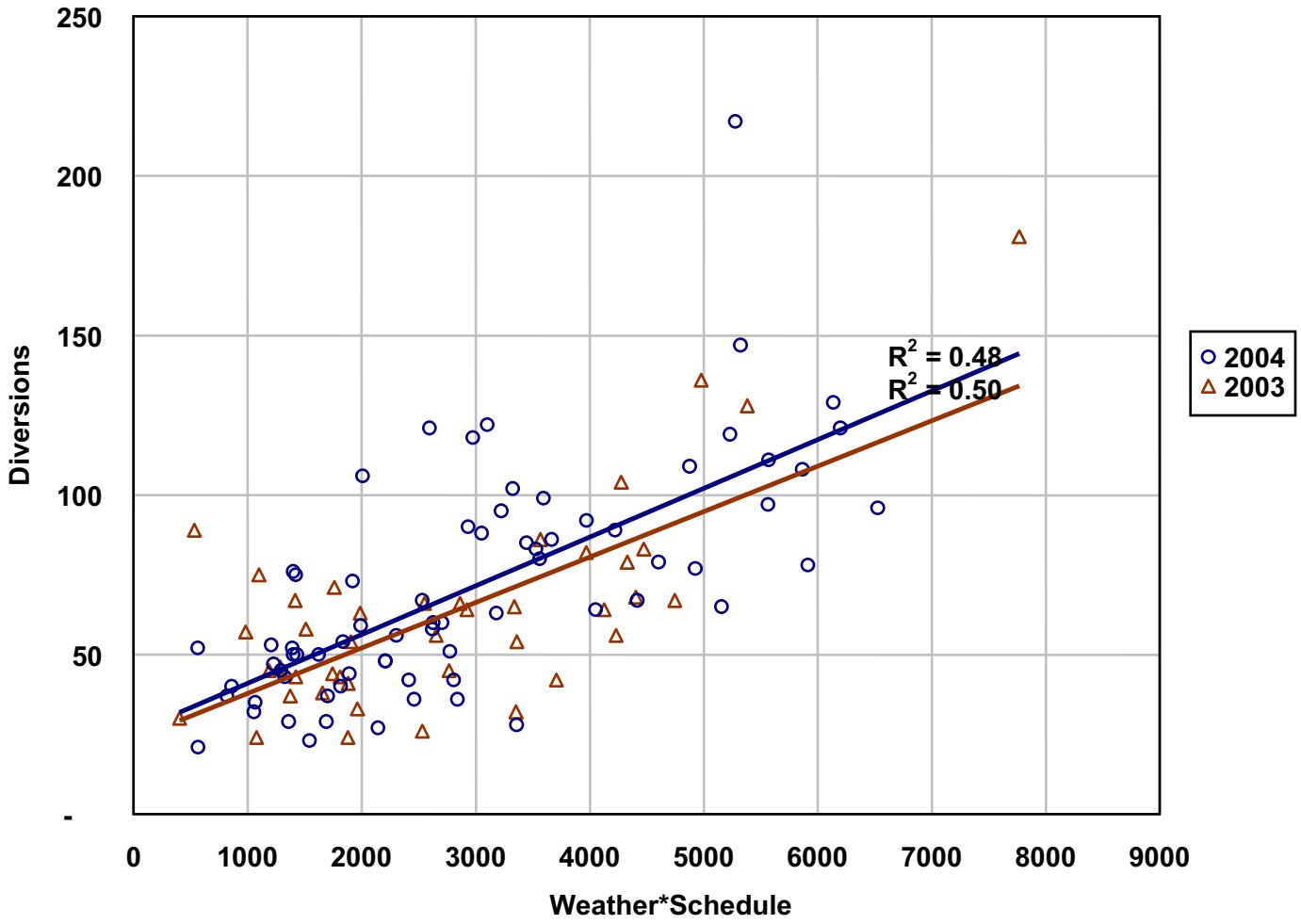
Airborne Holds Versus Weather Score 2003 and 2004



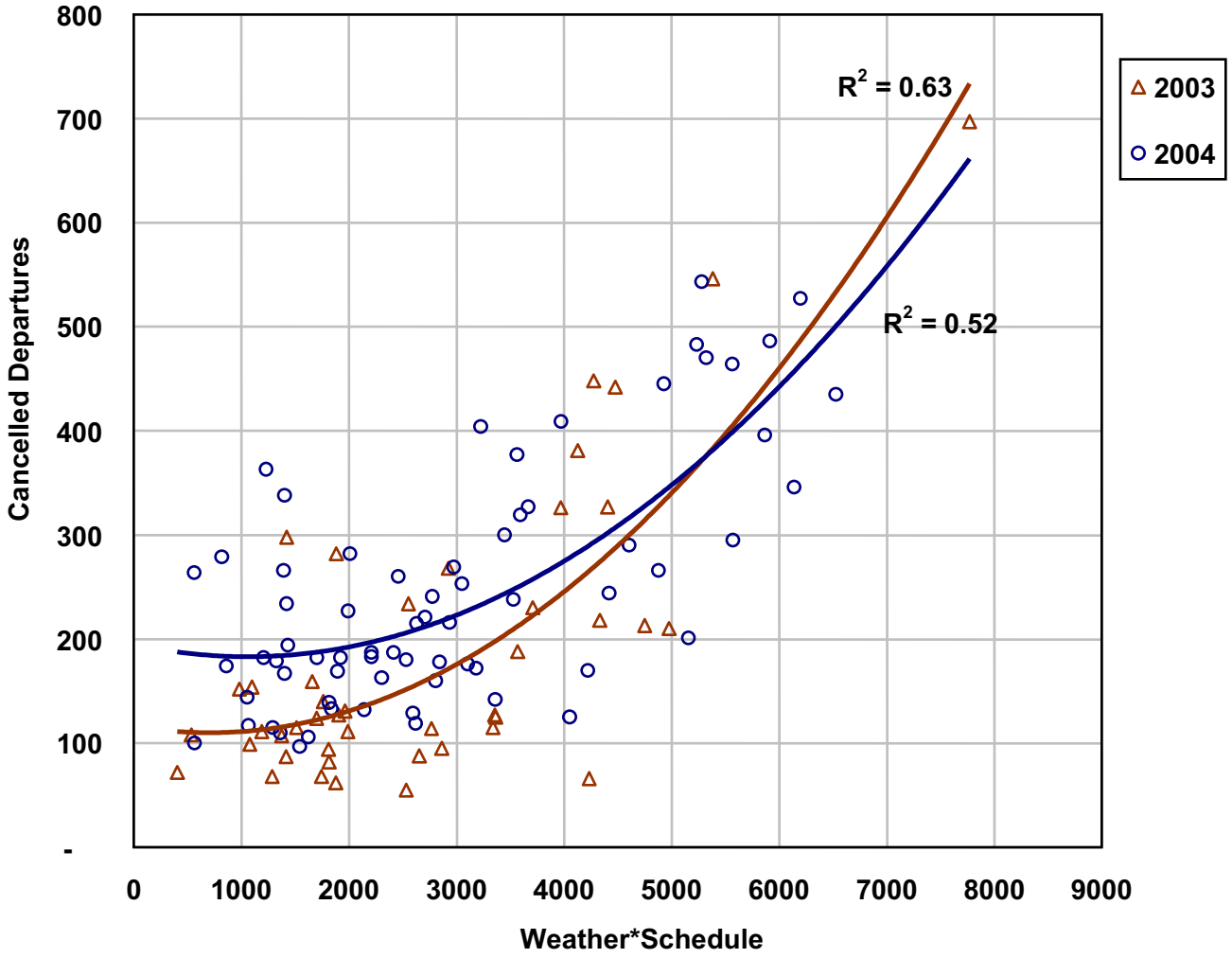
45 Airports

Diversions Versus Weather Score 2003 and 2004



45 Airports

Cancellations Versus Weather Score 2003 and 2004



45 Airports

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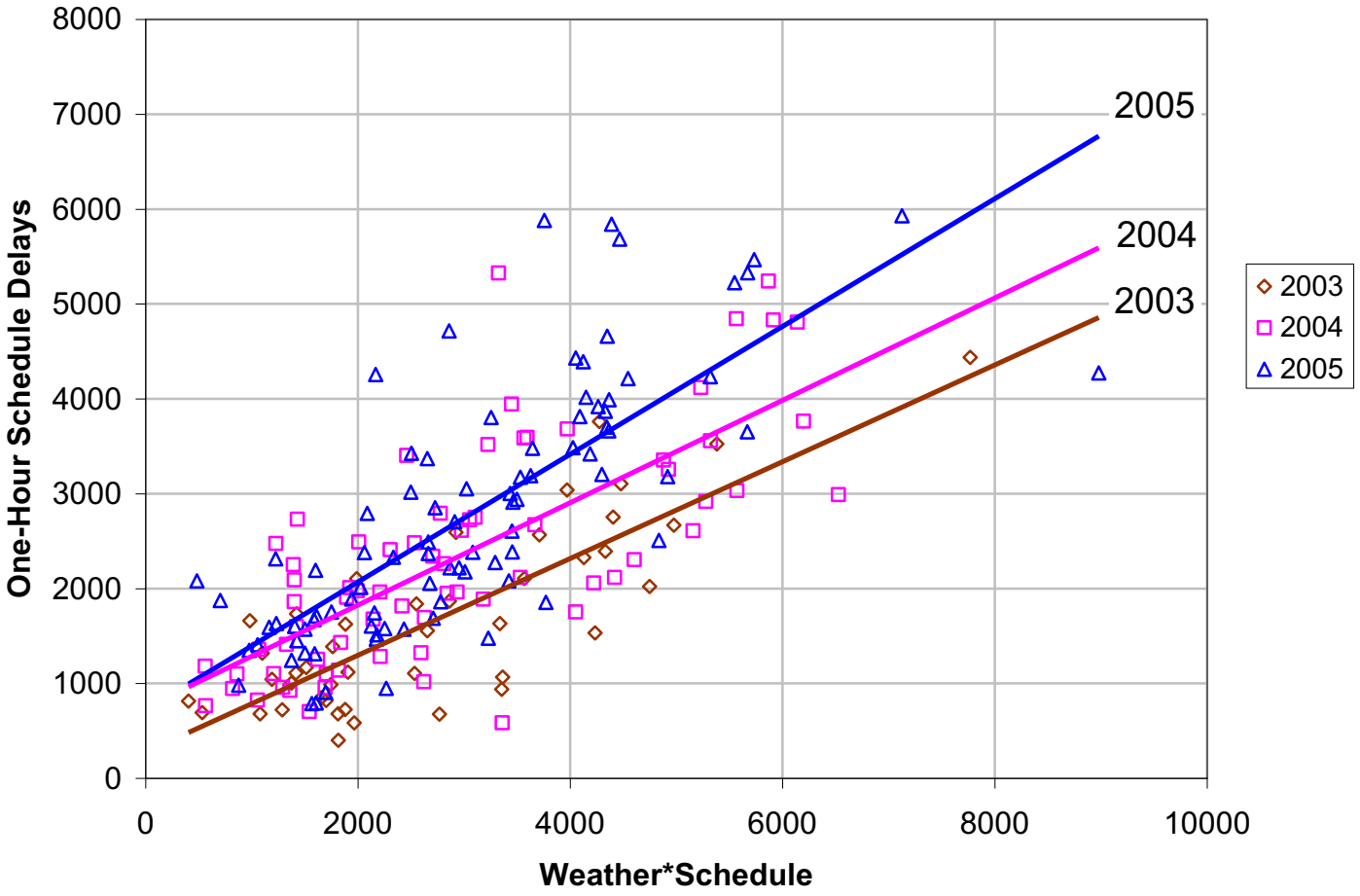
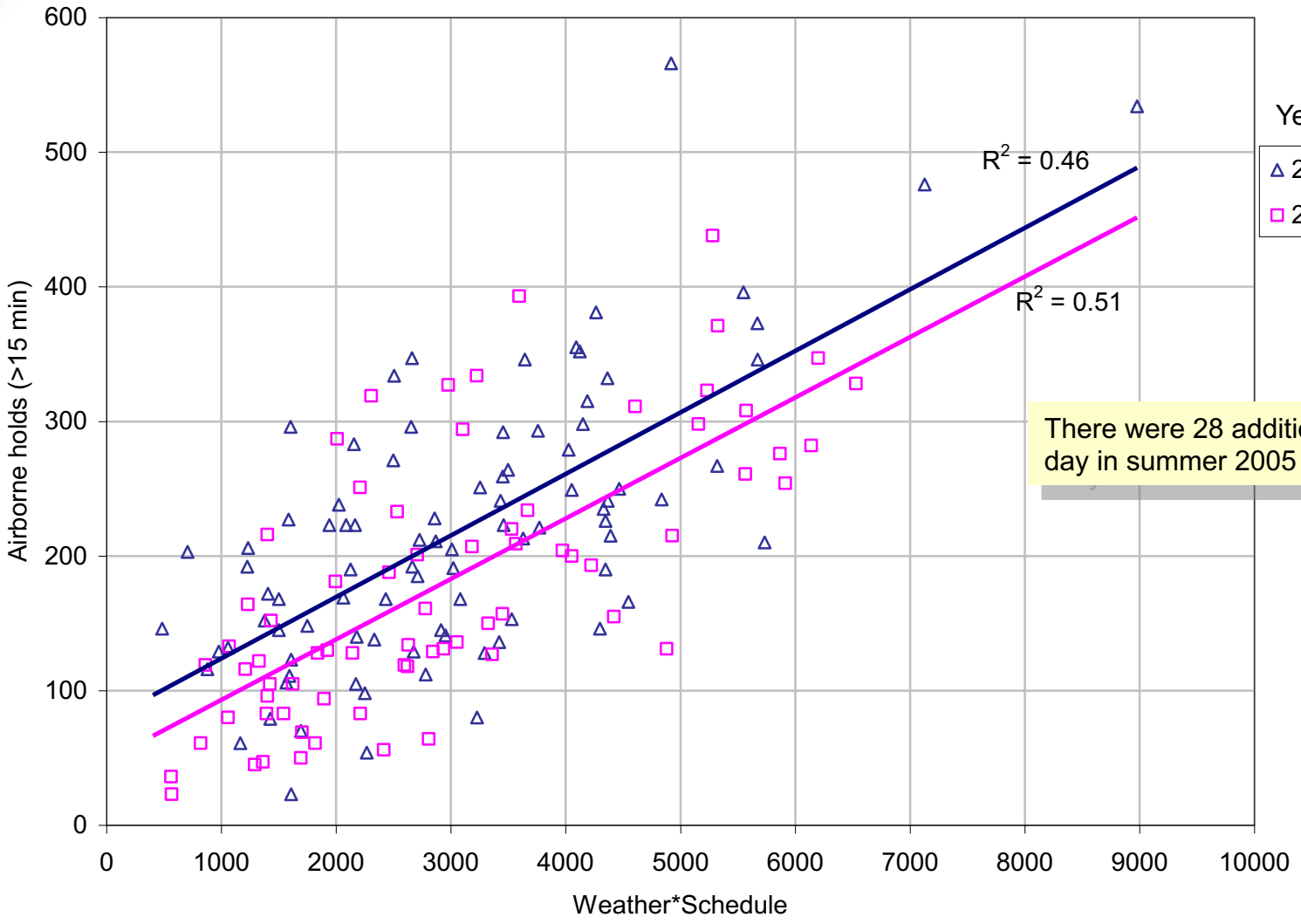
Delays Versus Weather Score 2003, 2004, and 2005



45 Airports

Airborne Holding Up in Summer 2005



There were 28 additional holds per day in summer 2005 compared to 2004

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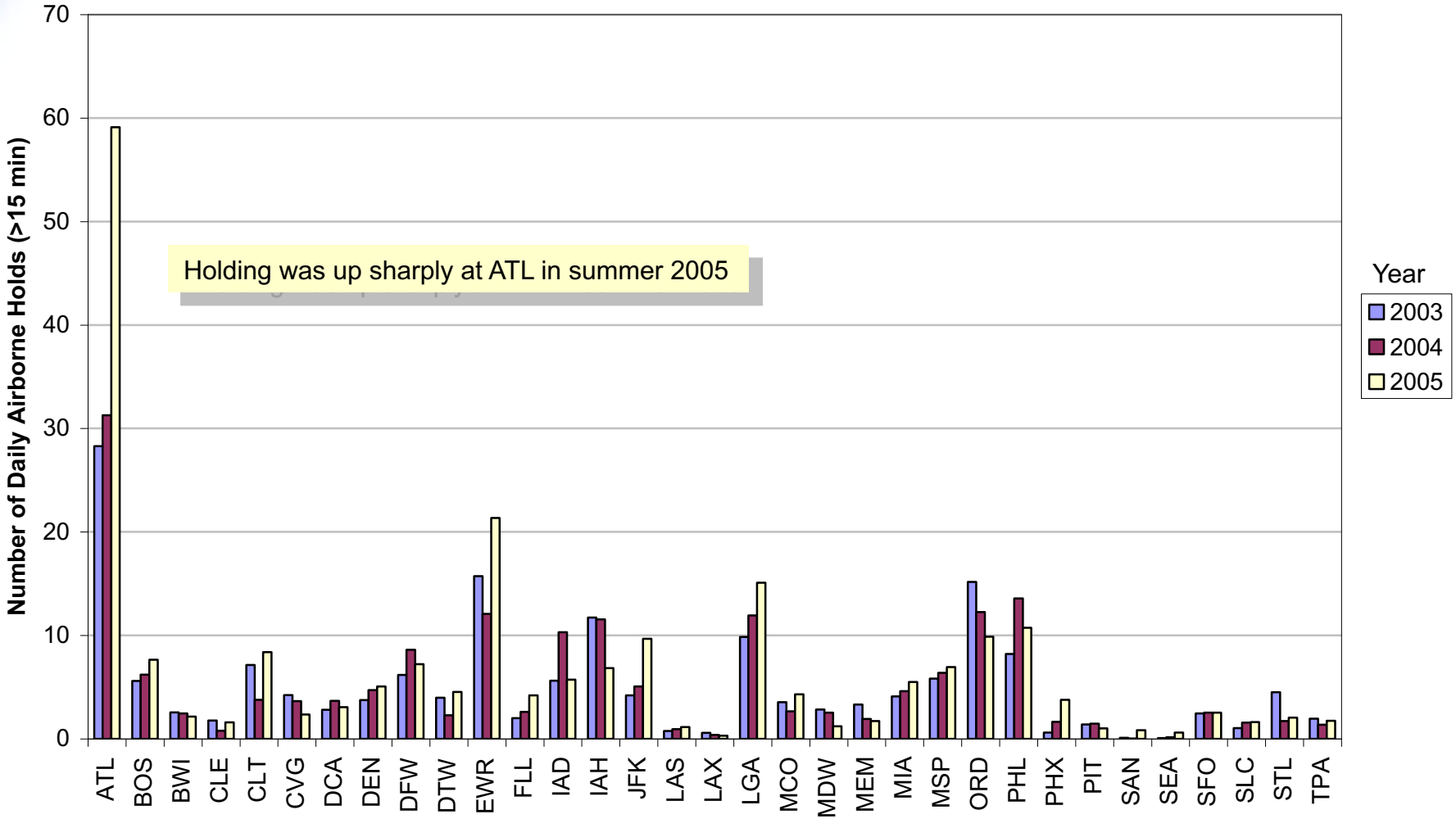
Airborne Holding Up in Summer 2005



*June-August

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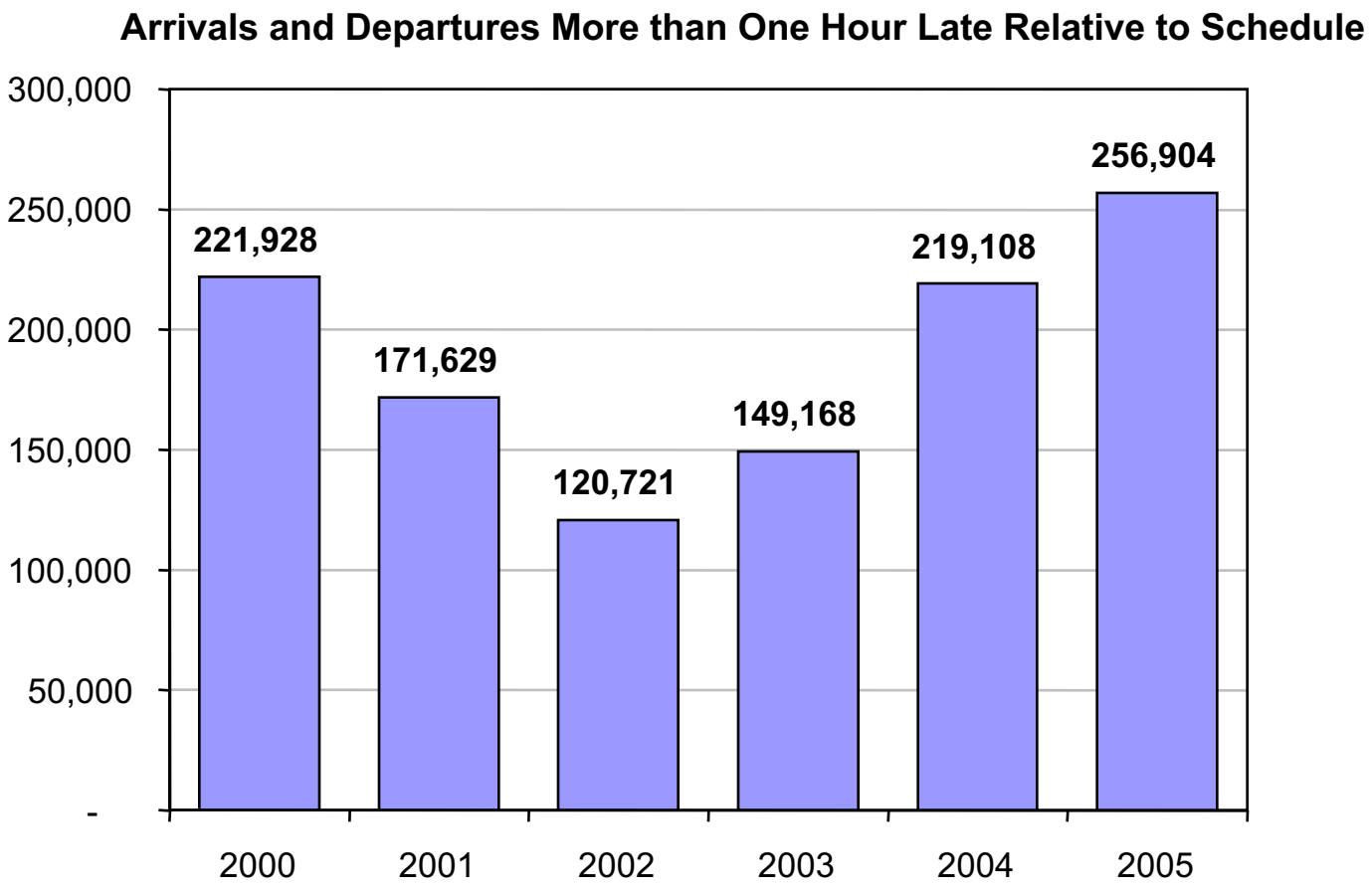
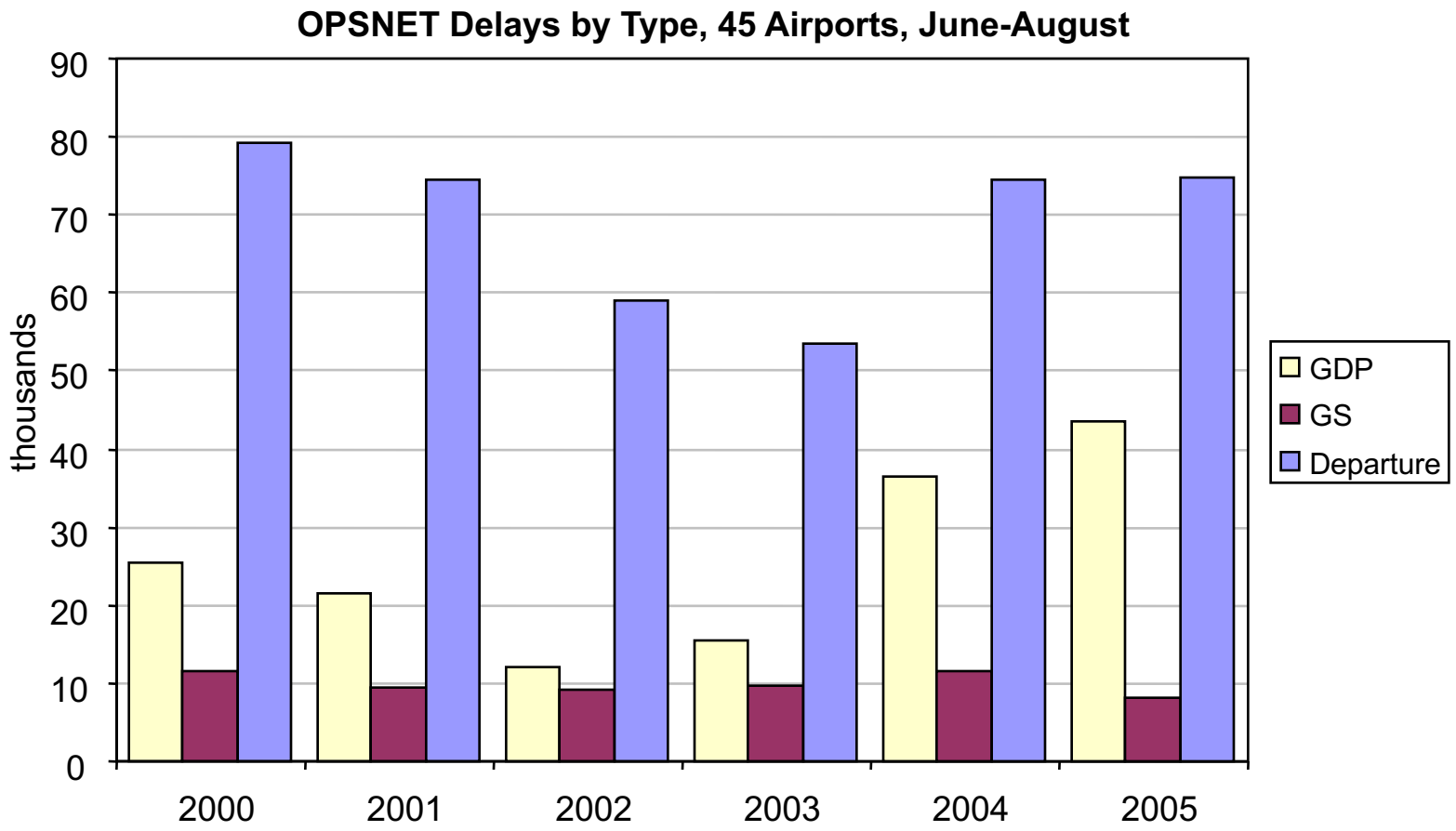
Schedule Delays Lasting More Than One Hour Up 16% Compared to 2000



Source: ASPM, 45 Airports

Delays Due to GDPs Up in 2004 and 2005



Source: OPSNET, includes delays attributed to en route centers

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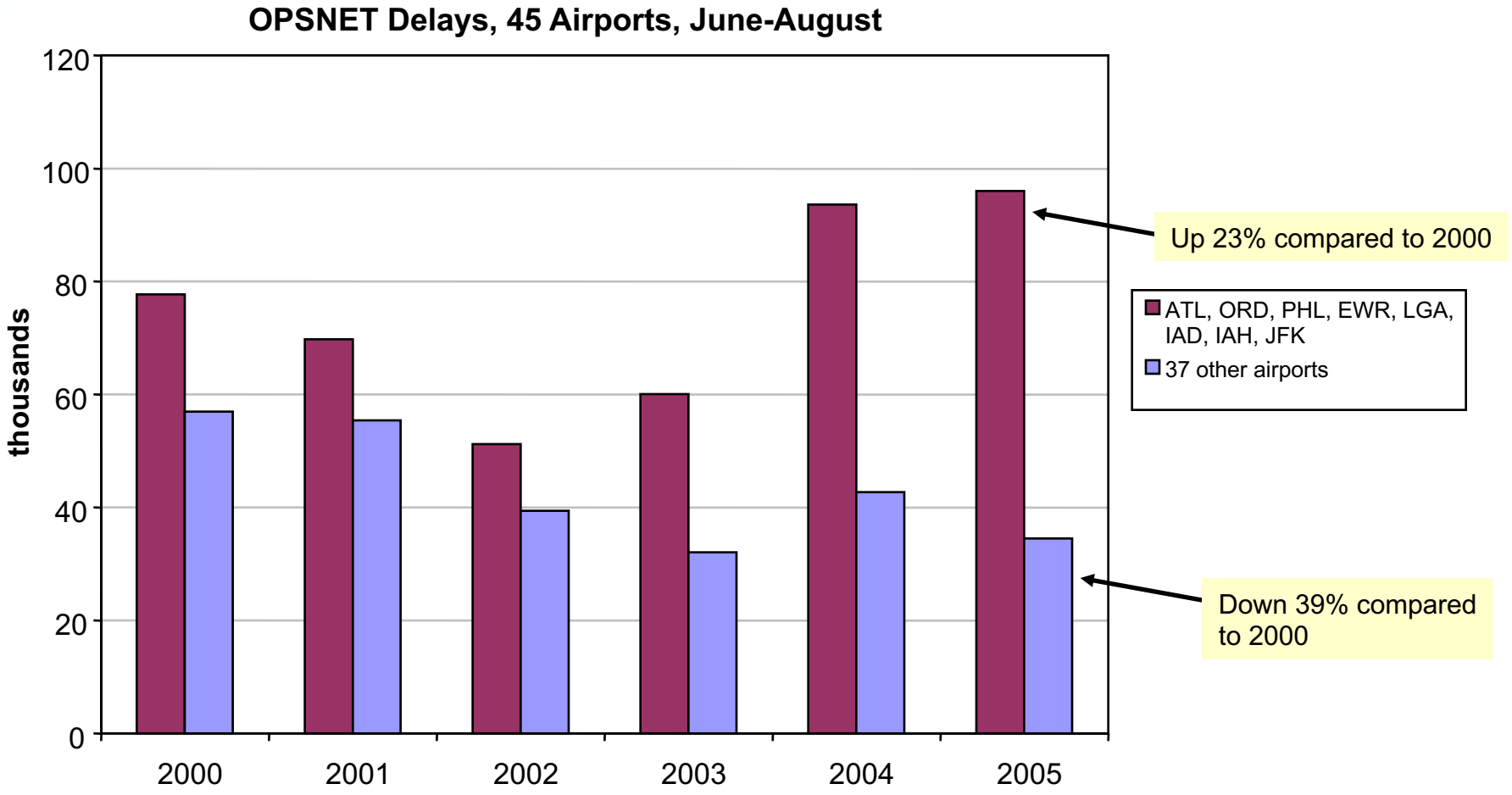
Proportion of OPSNET Delays at the 8 Most Delayed Airports Has Grown



Includes delays attributed to ARTCCs. Delays up 7% overall compared to 2000

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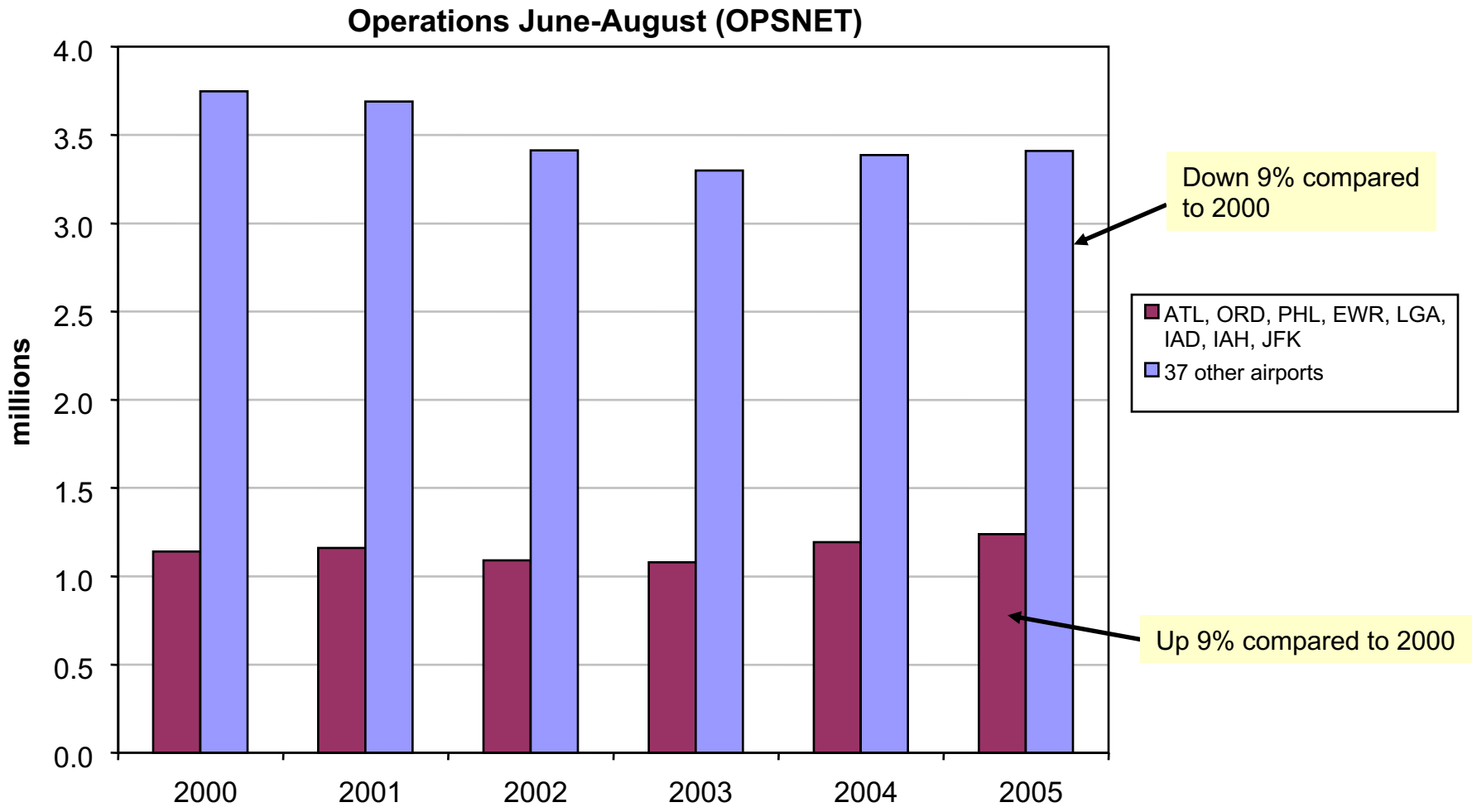
Operations, on Average, Up 9% at the 8 Most Delayed Hubs, and Down 9% Elsewhere



Operations down 5% overall at OPSNET 45 airports compared to 2000

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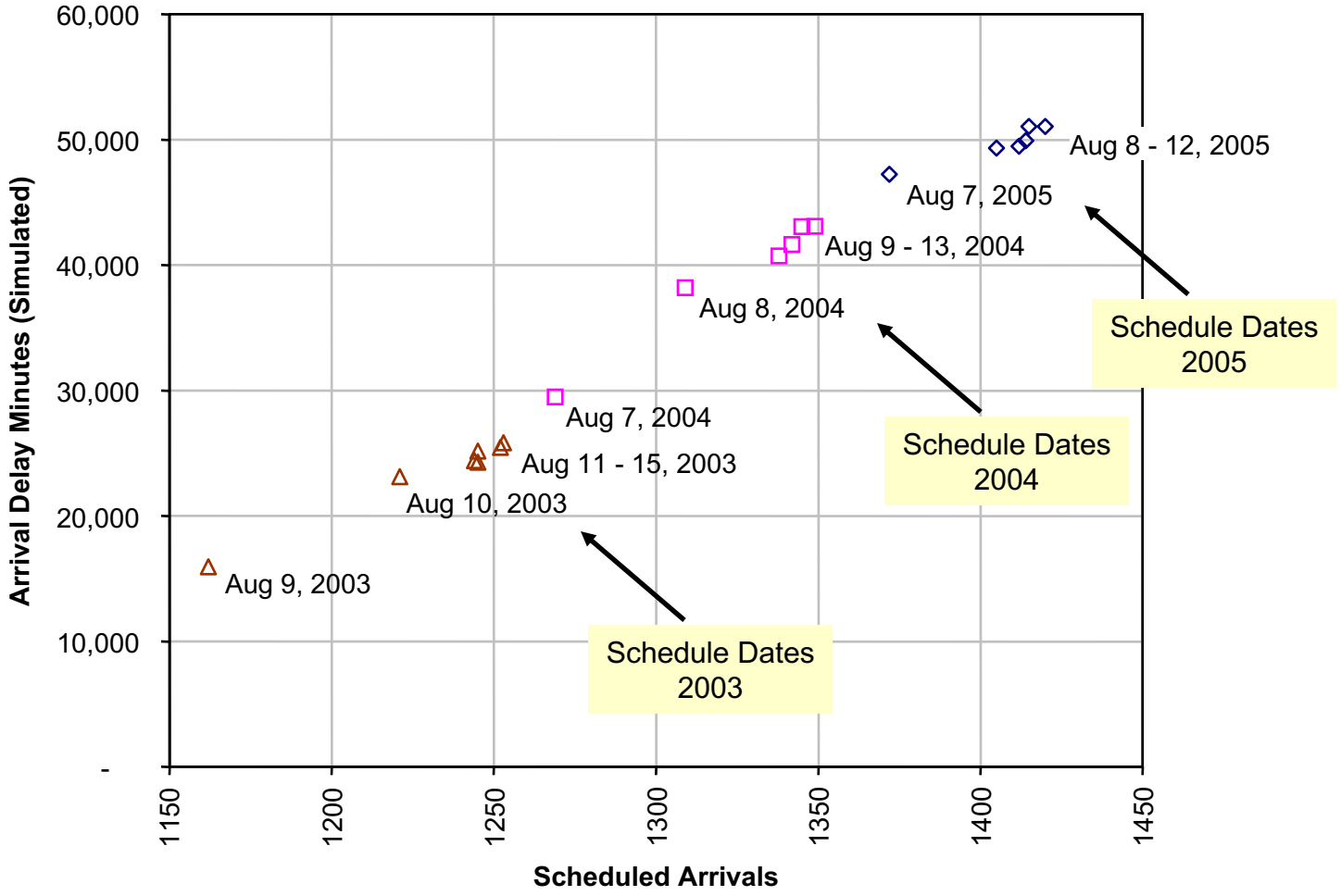
ATL Simulated Minutes of Arrival Delay Using Arrival Capacity from 8/7/05



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Summary

- Introduced a convective weather metric defined as the product of an airport's maximum hourly thunderstorm intensity and the number of flights scheduled to land that hour
- Metric has several advantages
  - Can be aggregated and disaggregated
  - Small, computationally simple dataset
  - Yields many insights about NAS performance

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Other Findings

- **Factoring out differences in weather and the total number of scheduled ops, hour-long delays increased substantially from 2003 to 2004 and from 2004 to 2005**
  - **Increases caused by greater concentration of traffic at already delayed airports**
- **Airborne holding and diversions were unchanged from 2003 to 2004, however, holding increased from 2004 to 2005**

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And Lastly

- **Similar approaches for measuring system performance based on delays, cancellations, diversions, holding, etc. ought to yield results similar to those presented here.**

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Appendix

CAASD

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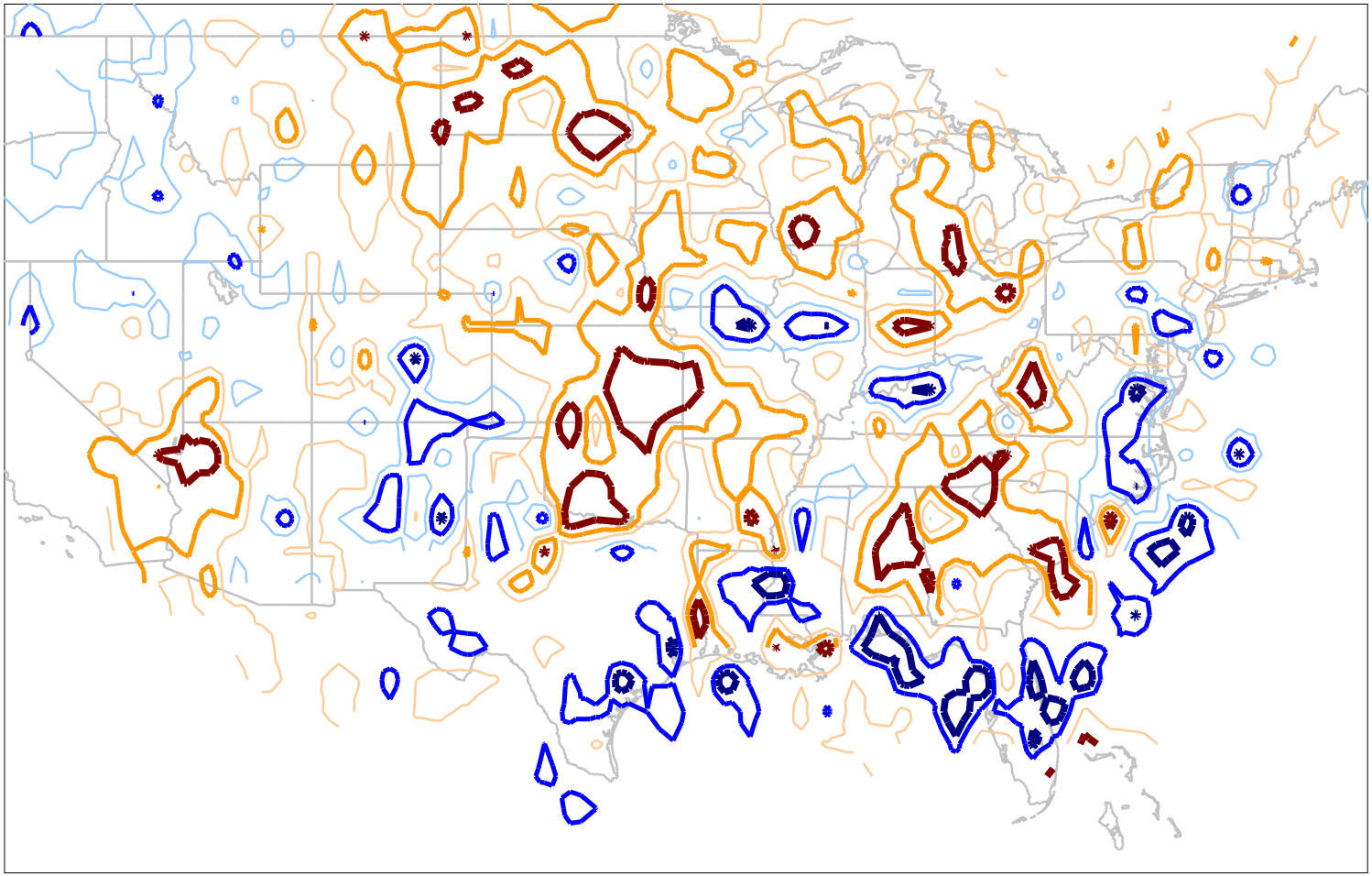
Number of Hours Having Thunderstorm Intensity>3 (June – August 2005 Minus June – August 2004)



Source: National Convective Weather Detection

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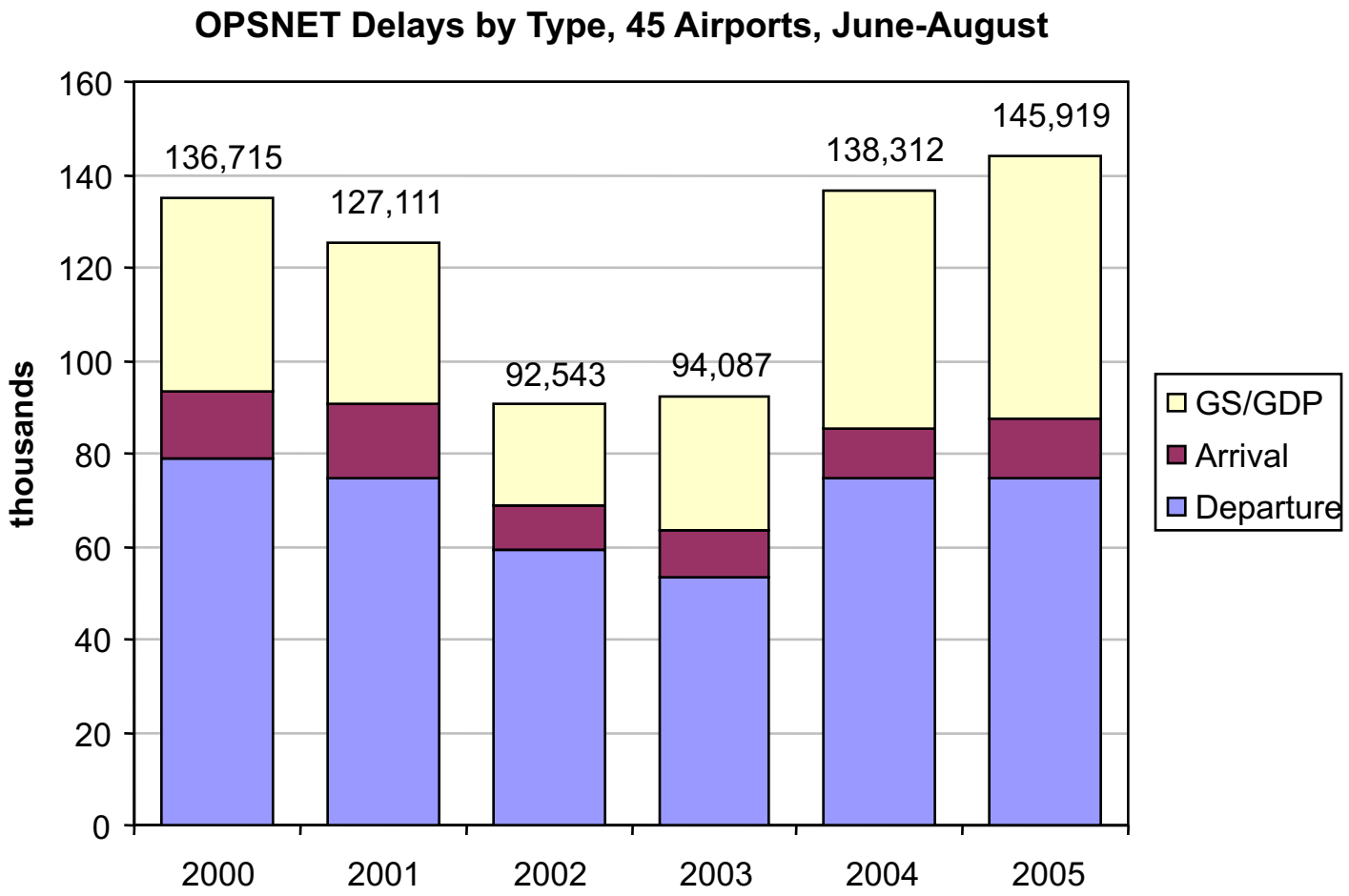
OPSNET Delays Up 7% Compared to 2000



Source: OPSNET, includes delays attributed to en route centers

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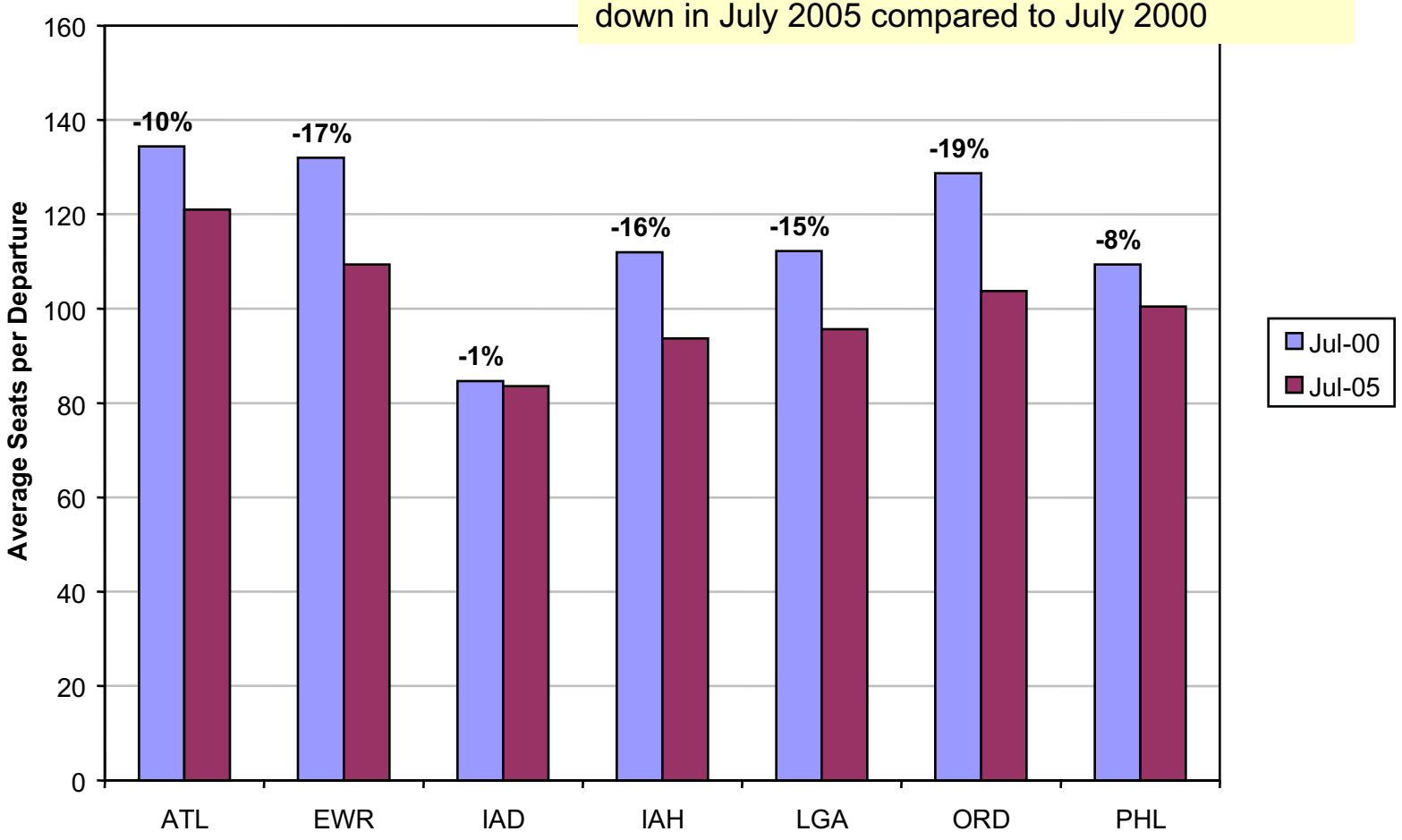
Average Number of Seats per Departure has Decreased

Average number of seats per scheduled departure down in July 2005 compared to July 2000



Source: OAG

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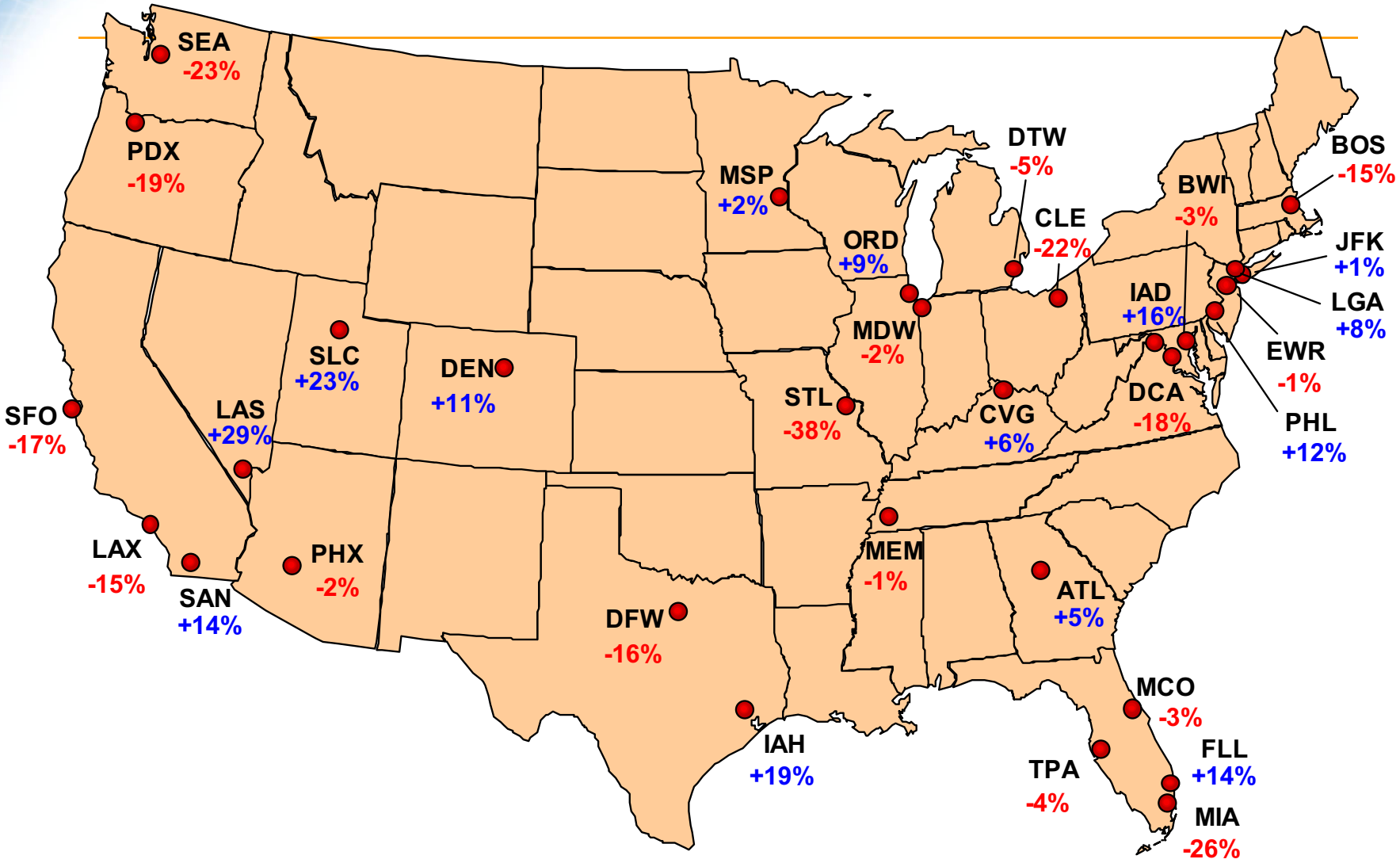
Change in Operations by Major Airport

Summer 2005 vs Summer 2000



Source: OPSNET, Overall change = -2%, 35 Airports

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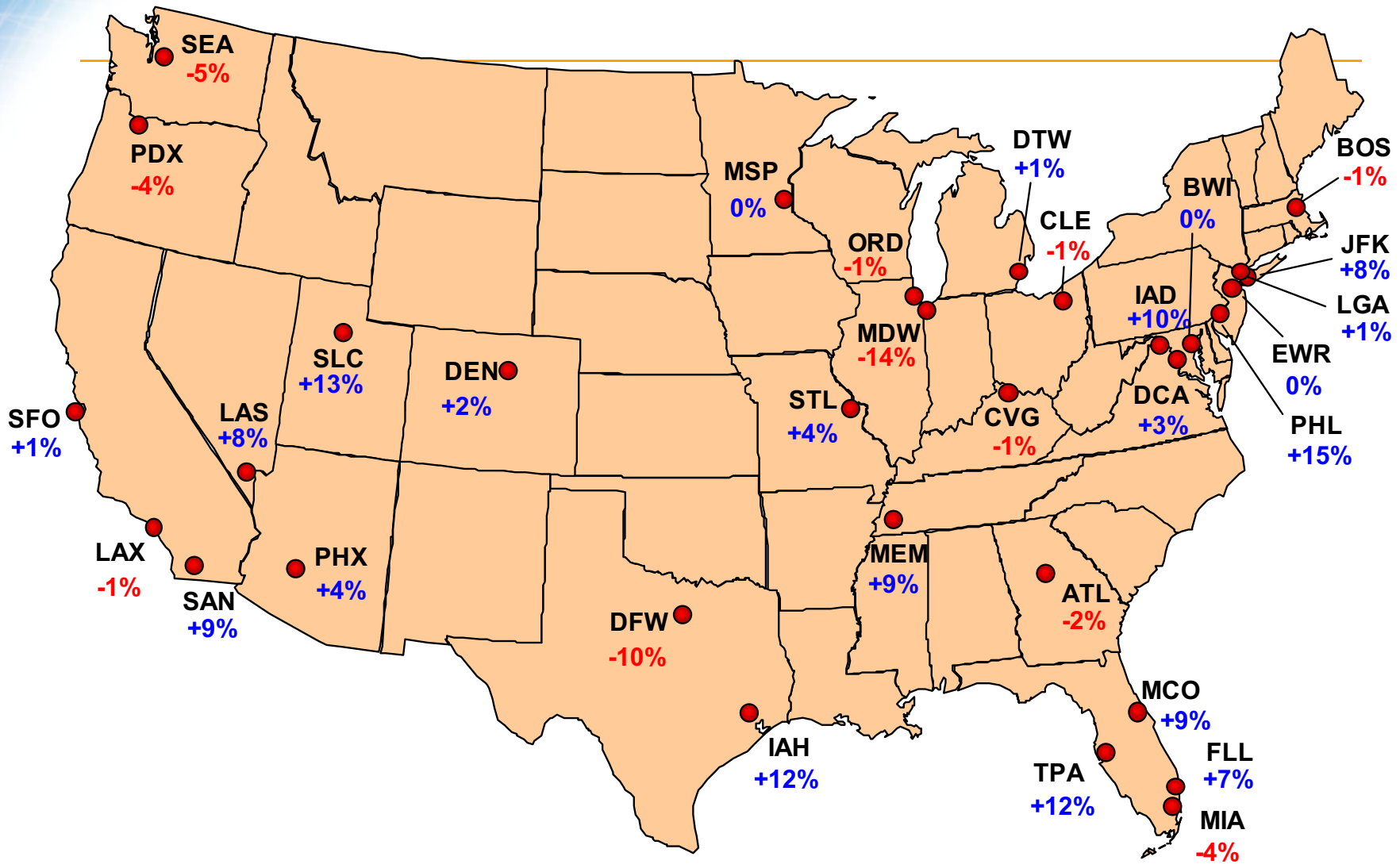
Change in Operations by Major Airport

Summer 2005 vs Summer 2004



Source: OPSNET, Overall change = -2%, 35 Airports

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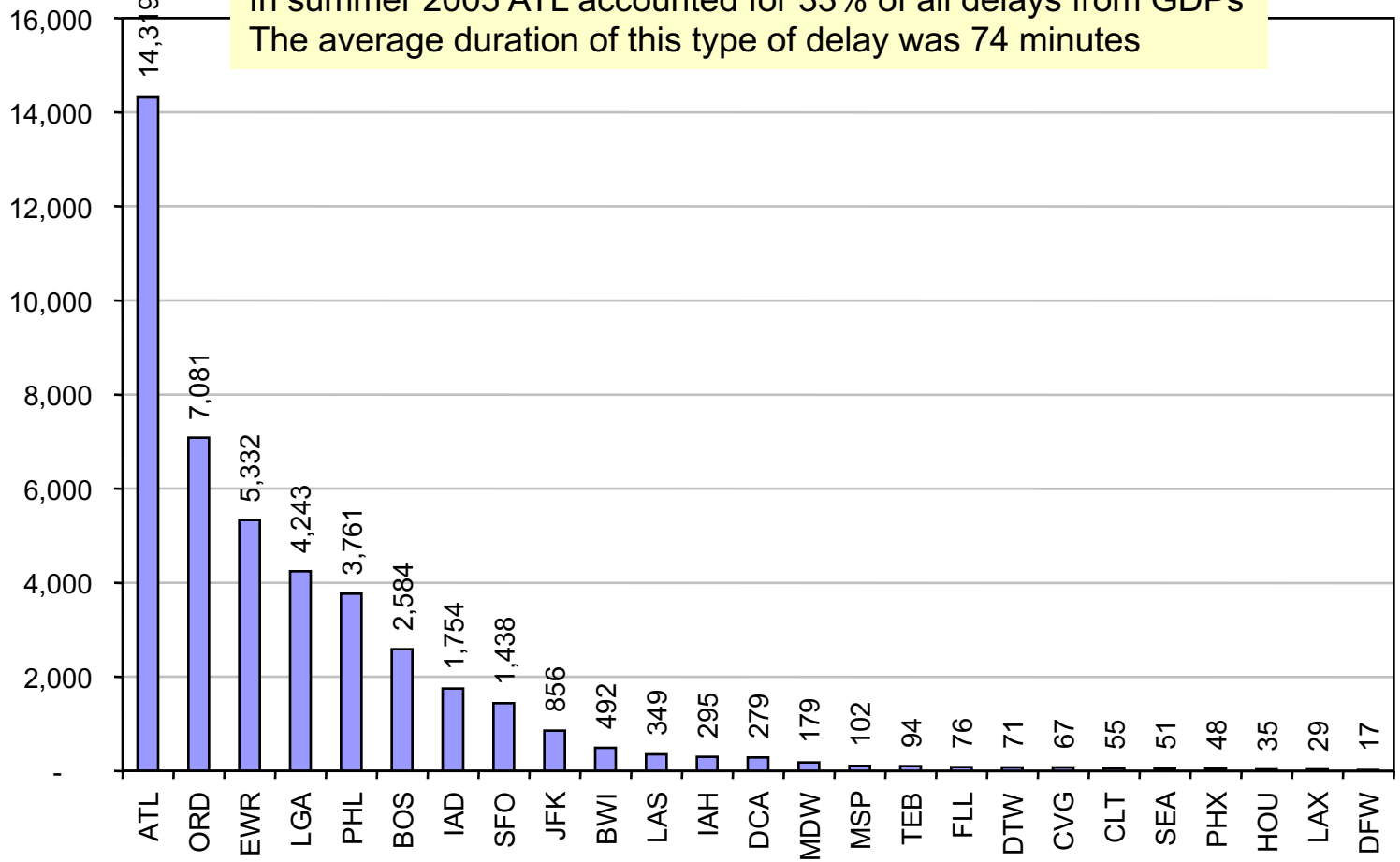
Delays from GDPs: June – August 2005

In summer 2005 ATL accounted for 33% of all delays from GDPs
The average duration of this type of delay was 74 minutes



Source: OPSNET

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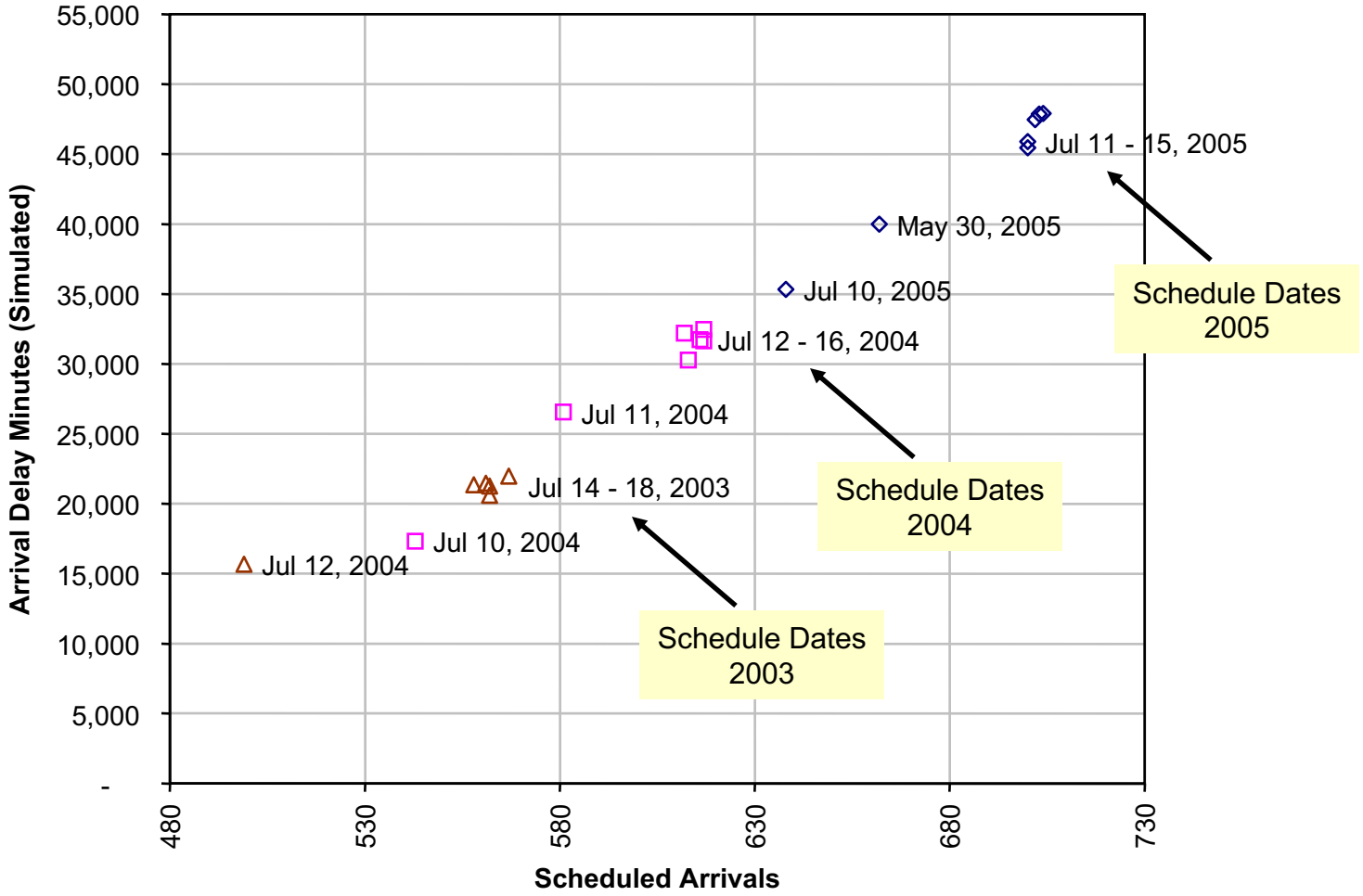
PHL Simulated Minutes of Arrival Delay Using Arrival Capacity from 7/13/05



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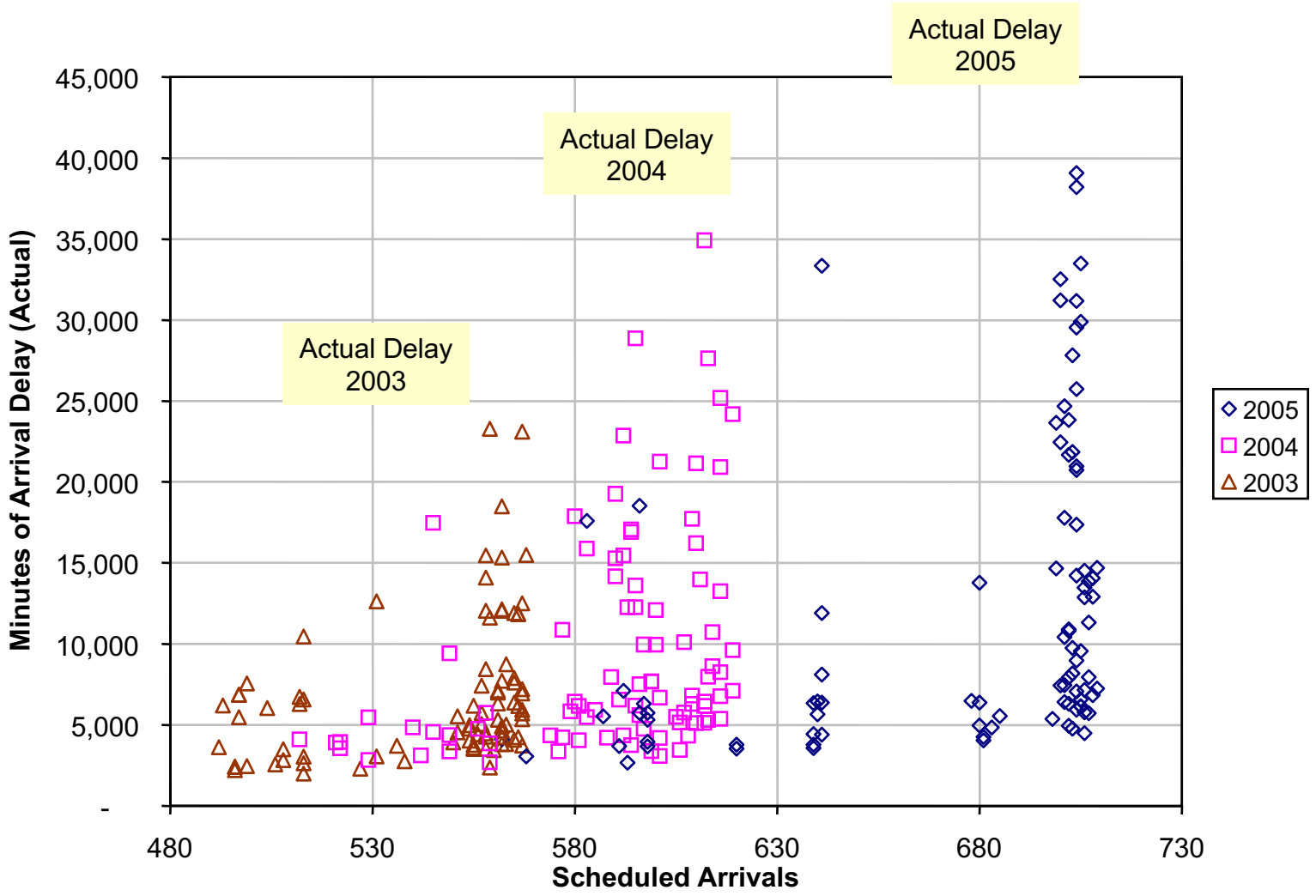
PHL: Actual Minutes of Arrival Delay, June – August



Source: ASPM, Each point represents one day, one outlier day excluded from 2003 and 2004

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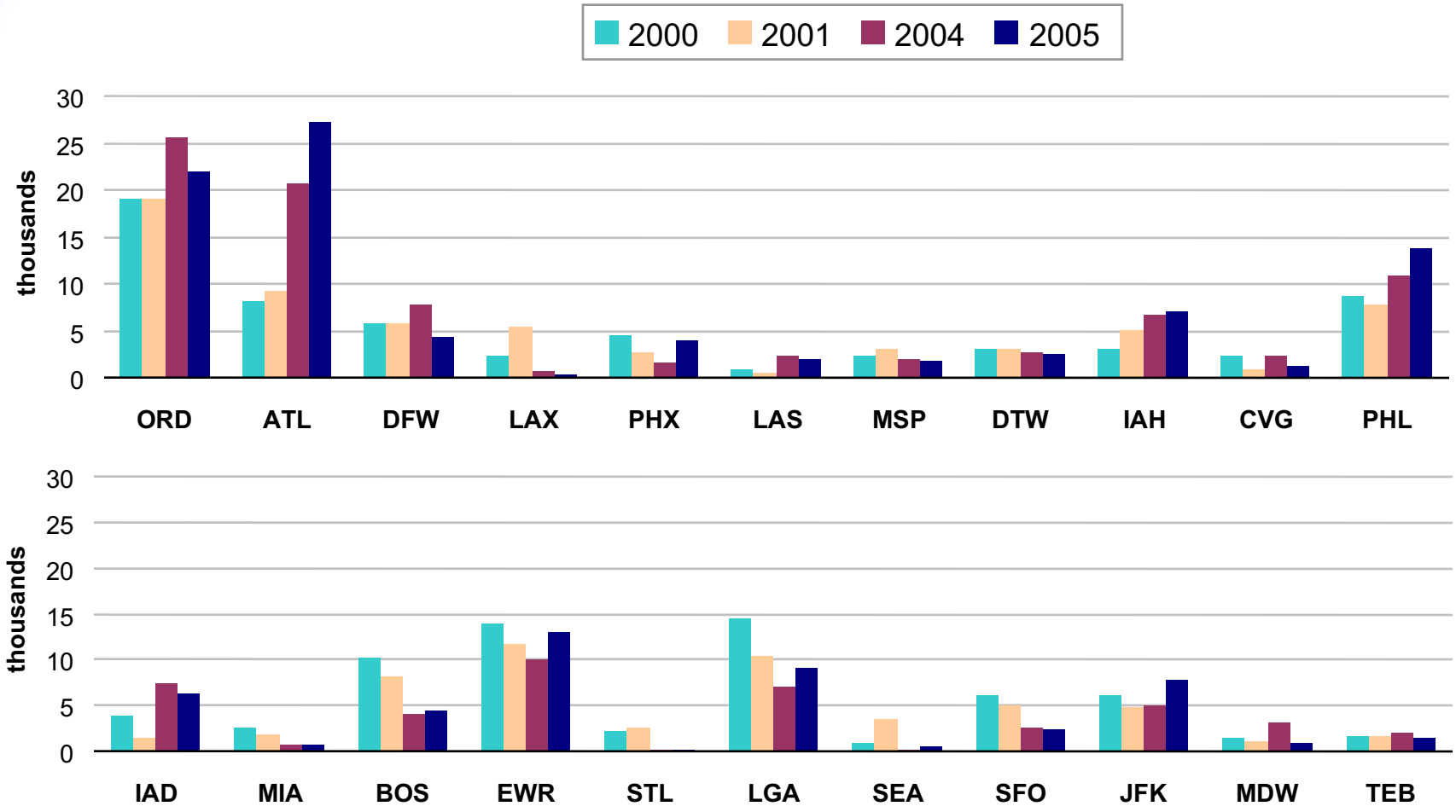
OPSNET Delays for 22 Most Delayed Airports: June – August



Ordered by busiest airport, includes delays attributed to en route centers

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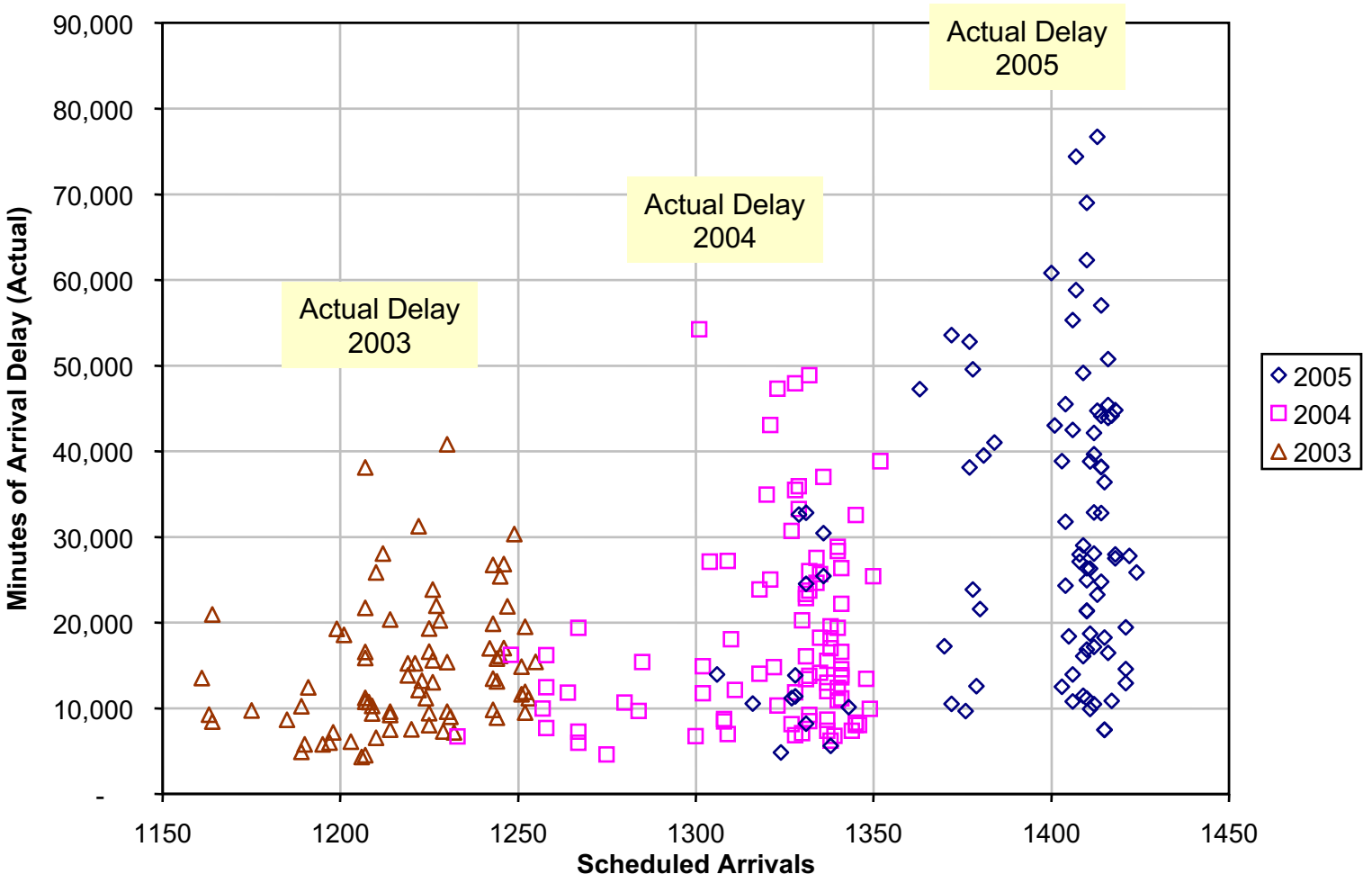
ATL: Actual Minutes of Arrival Delay, June – August



Source: ASPM, Each point represents one day, two outlier days excluded from 2003 and 2004

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To Improve Airport Model

- Adding a variable representing amount of system-wide delay raises r-squared to 0.66 for ATL
- For ORD two-variable model has r-squared of 0.71

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Three-Letter Airport Abbreviations

ABQ	-	Albuquerque International Sunport
ATL	-	Atlanta International
BNA	-	Nashville International
BOS	-	Boston/Logan International
BWI	-	Baltimore-Washington International
CLE	-	Cleveland-Hopkins International
CLT		Charlotte/Douglas Internationa
CVG	-	Covington/Cincinnati International
DCA	-	Reagan National
DEN	-	Denver International
DFW	-	Dallas-Ft Worth International
DTW	-	Detroit Metro Wayne Co
EWR	-	Newark International
FLL	-	Fort Lauderdale/Hollywood International
HOU	-	William P. Hobby Airport
IAD	-	Washington Dulles International
IAH	-	Houston/G Bush Intercontinental
IND	-	Indianapolis International
JFK	-	John F Kennedy International
LAS	-	Las Vegas/Mc Carran International
LAX	-	Los Angeles International
LGA	-	La Guardia
MCI	-	Kansas City International
MCO	-	Orlando International
MDW	-	Chicago Midway
MEM	-	Memphis International
MIA	-	Miami International
MSP	-	Minneapolis St Paul International
MSY	-	New Orleans International
OAK	-	Metropolitan Oakland International
ORD	-	Chicago O'Hare International
PBI	-	Palm Beach International
PDX	-	Portland International
PHL	-	Philadelphia International
PHX	-	Phoenix Sky Harbor International
PIT	-	Pittsburgh International
RDU	-	Raleigh-Durham International
SAN	-	San Diego International
SEA	-	Seattle Tacoma International
SFO	-	San Francisco International
SJC	-	San Jose International
SLC	-	Salt Lake City International
STL	-	Lambert-St Louis International
TEB	-	Teterboro
TPA	-	Tampa International

Glossary

ASPM	Aviation System Performance Metrics
FSL	Forecast Systems Laboratory
GDP	Ground Delay Program
NAS	National Airspace System
NOAA	National Oceanic & Atmospheric Administration
OAG	Official Airline Guide
OPSNET	Operations Network
US	United States
Z	Zulu Time