Equity and Equity Metrics in Air Traffic Flow Management

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Equity and CDM

- Traditional Air Traffic Flow Management: central decision-maker paradigm – traffic flow managers allocate resources to individual flights so as to maximize system efficiency
- CDM philosophy:
  - distribute decisions to entities with best information necessary to make decision
  - wherever possible give users control over any decision that involves economic tradeoffs
- One implementation of CDM philosophy: traffic flow manager allocates resources to airlines, airlines allocate resources "they own" to individual flights

  … what criteria should be used for allocating resources to airlines?? … equity!!!

Equity Concepts and Criteria

- ***First-come, first-served:***

  Provide air traffic control service to aircraft on a "first-come, first-served" basis as circumstances permit, except the following … (FAA Order 7110.65N: Air Traffic Control 2-4-1 OPERATIONAL PRIORITY)

- ***First-scheduled, first-served:*** CDM/ration-by-schedule

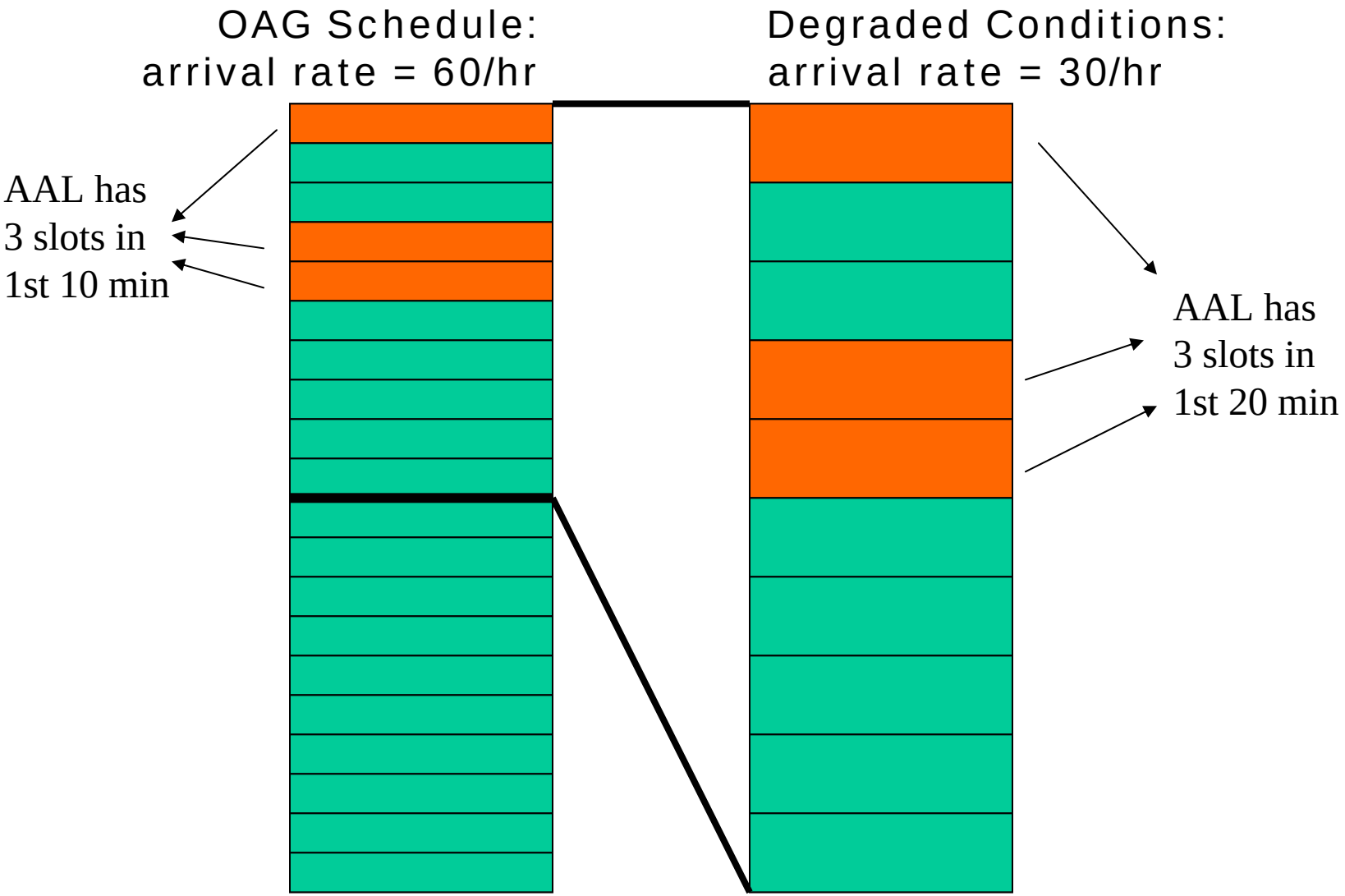
  Motivation: allocation is independent of flight status information → encourages airlines to provide up-to-date intent information

- Alternate interpretation of ration-by-schedule: schedule provides standard by which equity of allocation is measured

  Why is schedule a good standard?? It defines service to customers, represents investment on part of airlines and is (relatively) permanent.

- **General application: start by defining standard against which equity can be measured**

Basic RBS Allocation Principle



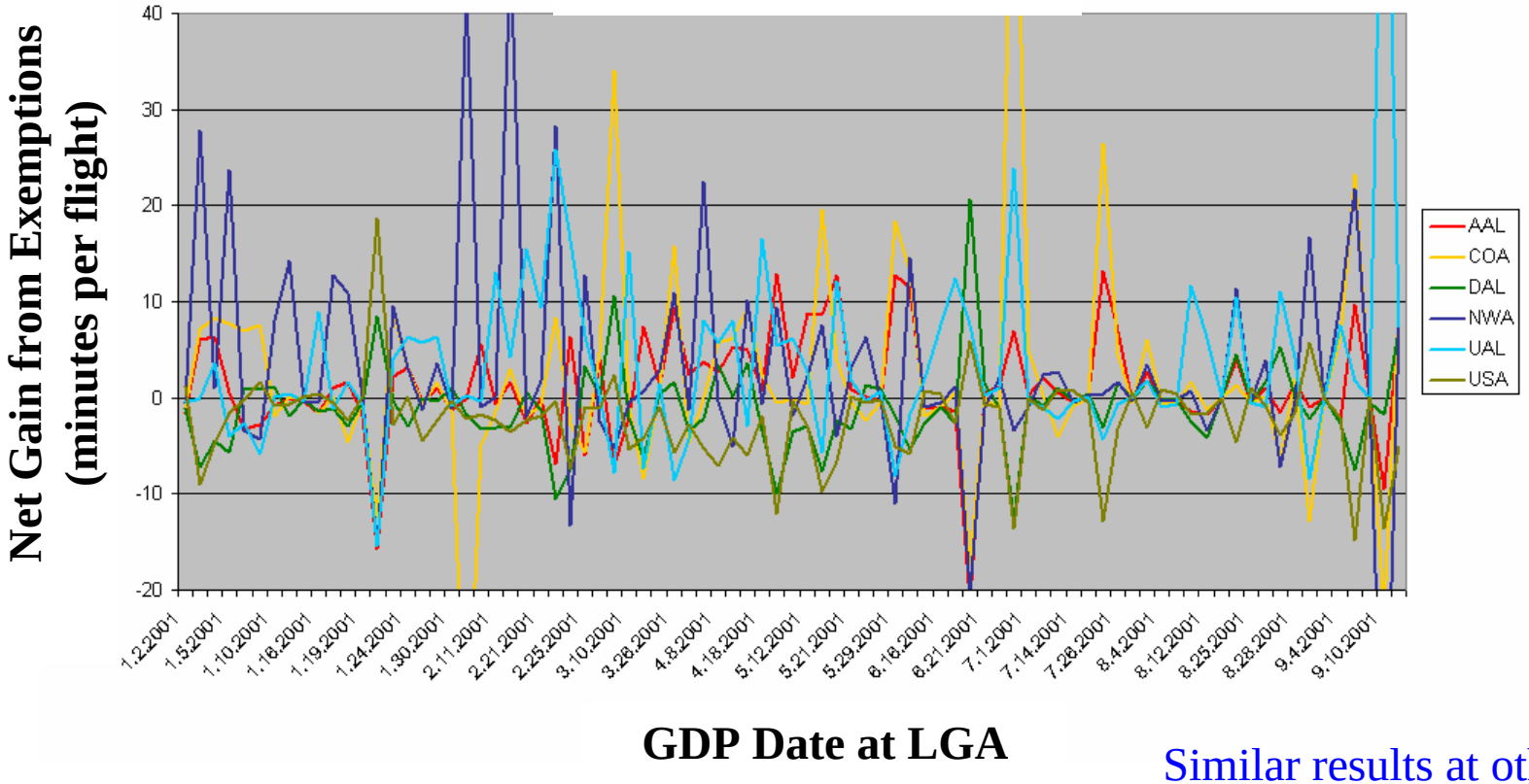
Key Properties of RBS

- Allocation independent of current status of flights ➔
  - Not affected by information provided by airlines ➔ no disincentive to provide information
- Based on simple, well-accepted priority scheme (first-come, first-served → first-scheduled, first-served).
- Delay allocation has all flights as “close to the average as possible”.
- The airlines and CDM community agree that it is fair!!

GDPs and Flight Exemptions

- GDPs are applied to an “included set” of flights
- Two significant classes of flights destined for the airport during the GDP time period are exempted:
  - Flights in the air
  - Flights originating at airports greater than a certain distance away from the GDP airport
- Question: Do exemptions induce a systematic bias in the relative treatment of airlines during a GDP??

Systematic Biases



Similar results at other airports

Mitigating Exemption Bias

Objective:

- Minimize deviation between actual allocation and ideal allocation

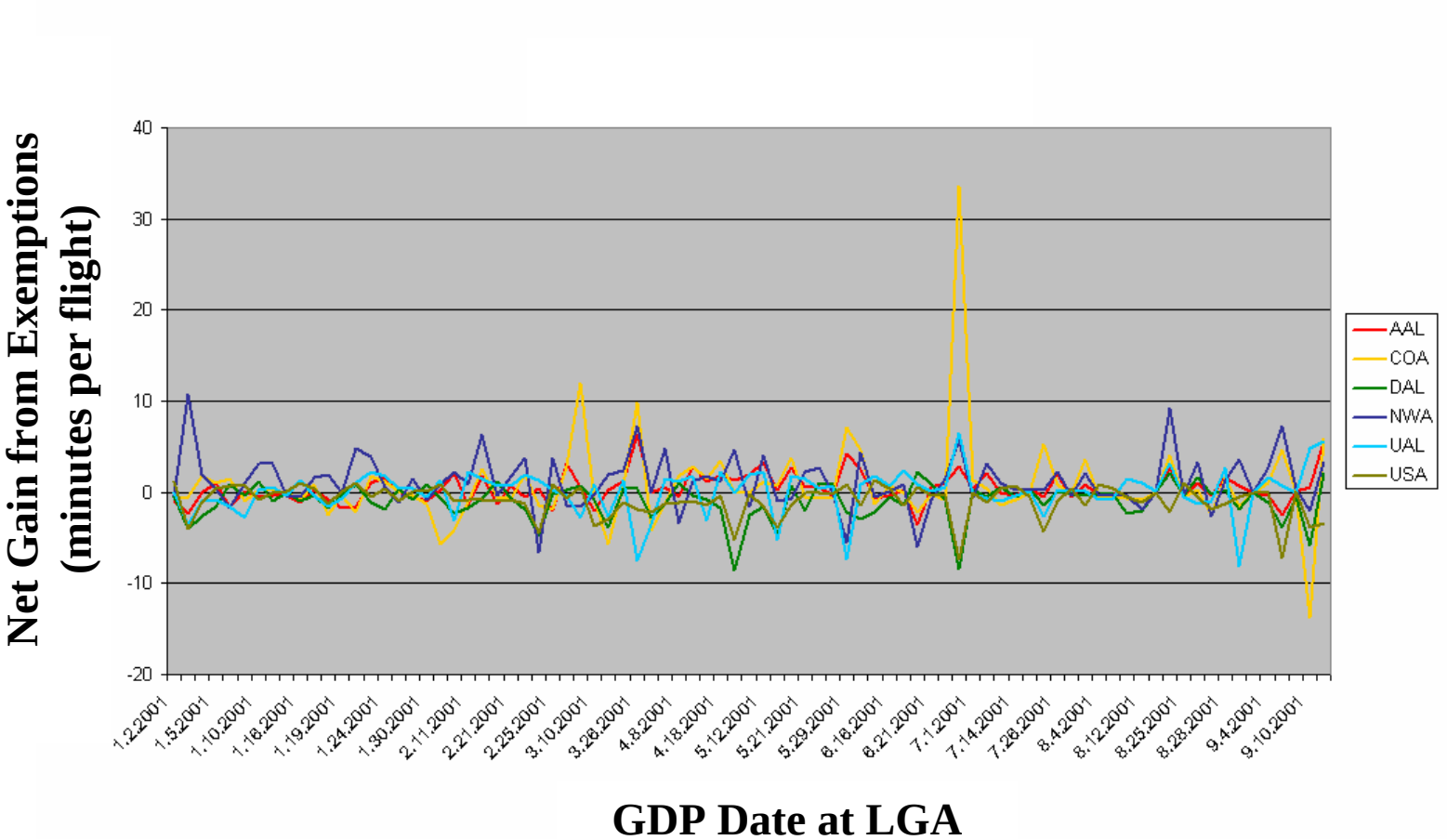
Approach:

- RBS applied to all flights whose arrival times fall within GDP time window ➔ ideal allocation
- Set of exempted flights are defined as before (there are good reasons they are exempted)

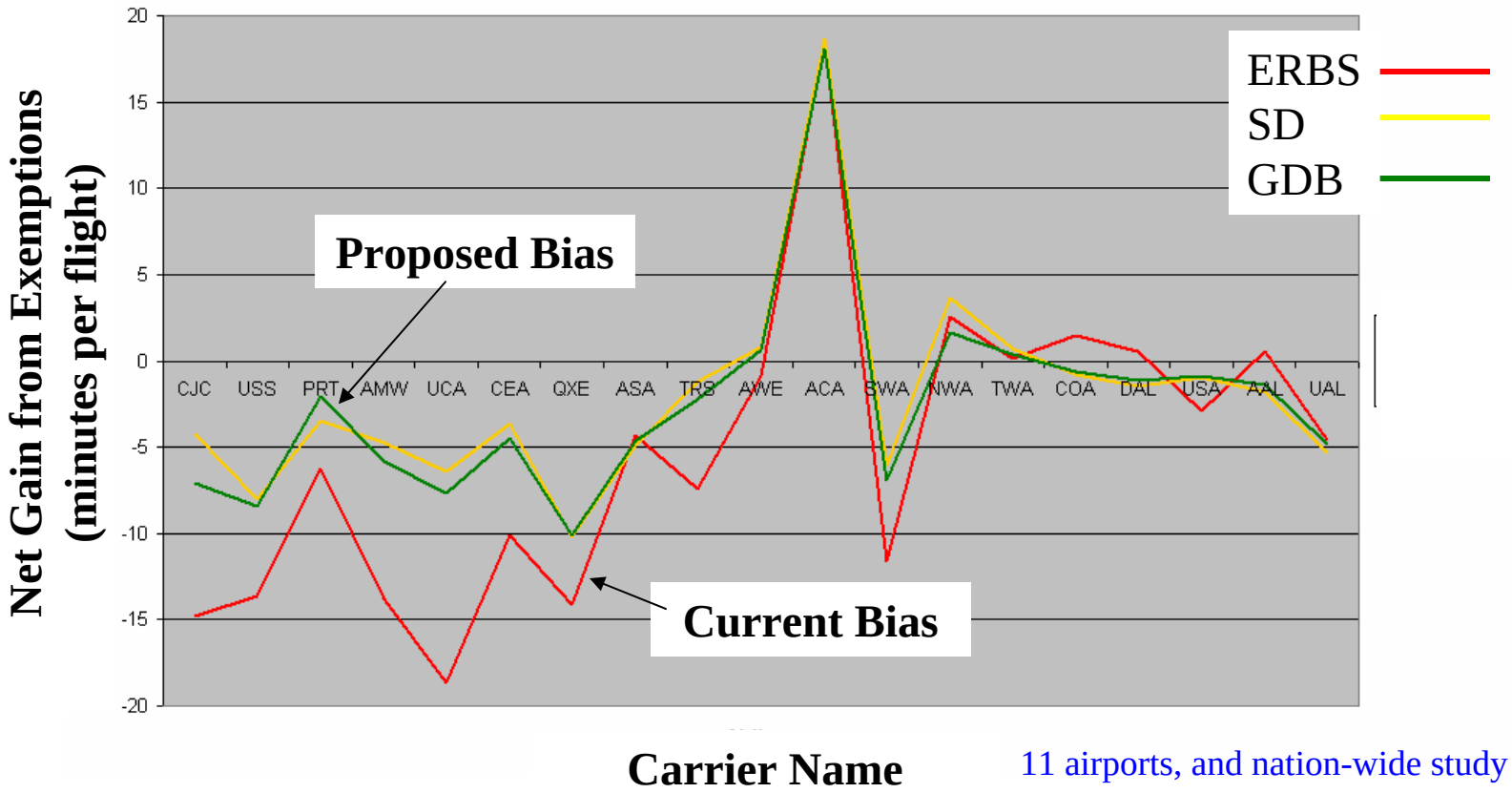
- Time slots given to exempted flights "count against" allocation
- Delays allocated to non-exempted flights so as to minimize overall deviation from ideal allocation
- Several alternative models derived: 2 discussed here (builds on just-in-time production scheduling research):
  - SD = slot deviation model;
  - GDB = global delay balancing

Ref: Vossen, Ball, Hoffman and Wambsganss, "A general approach to equity in traffic flow management and its application to mitigating exemption bias in ground delay programs", ATM 2003 – Best Paper Award

Bias Reduction From Global Delay Balancing Algorithm



The Lord Giveth and Taketh…



11 airports, and nation-wide study over 21 months (April 2000 to December 2001)

Defining a Metric

ADD(c,G) = average (per flight) delay deviation for air carrier c during GDP G.

nf(c,G) = number flights for air carrier c in GDP G

The scope of a metric is defined by the universe of GDPs the metric is defined over → UNIV

CDD(c) = carrier delay deviation

$= \sum_{G \in UNIV} ADD(c,G)\ nf(c,G) \ / \ \sum_{G \in UNIV} nf(c,G)$

CDD'(c) $= \sum_{G \in UNIV} |ADD(c,G)|\ nf(c,G) \ / \ \sum_{G \in UNIV} nf(c,G)$

Defining a Metric

EM = Equity Metric

$= \sum_c |CDD(c)| \, wgt(c) / \sum_c wgt(c)$

AEM = Absolute Equity Metric

$= \sum_c CDD'(c) \, wgt(c) / \sum_c wgt(c)$

Possible weights:

wgt(c) = num flights in UNIV for that airline

wgt(c) = 1

other??

Fundamental Questions in Defining Metric

- Scope??
  - Geographic
  - Temporal
- Carrier weights
- AEM vs EM
- What is equity standard??
  - alternatives to RBS
    - for GDPs
    - for enroute

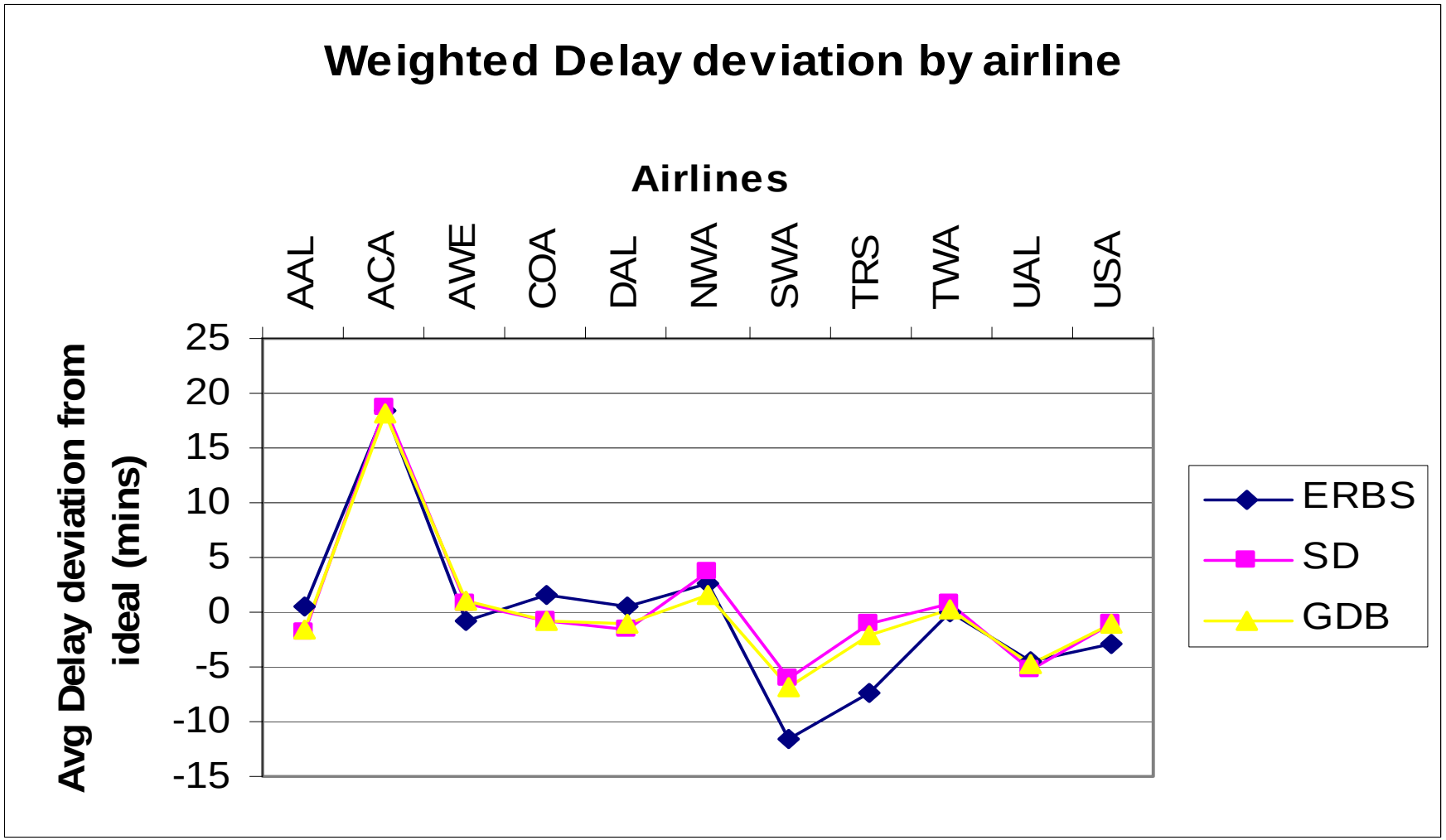
Scope and AEM vs EM

If a carrier got a bad deal today – is that made up for by a good deal tomorrow – two extremes:

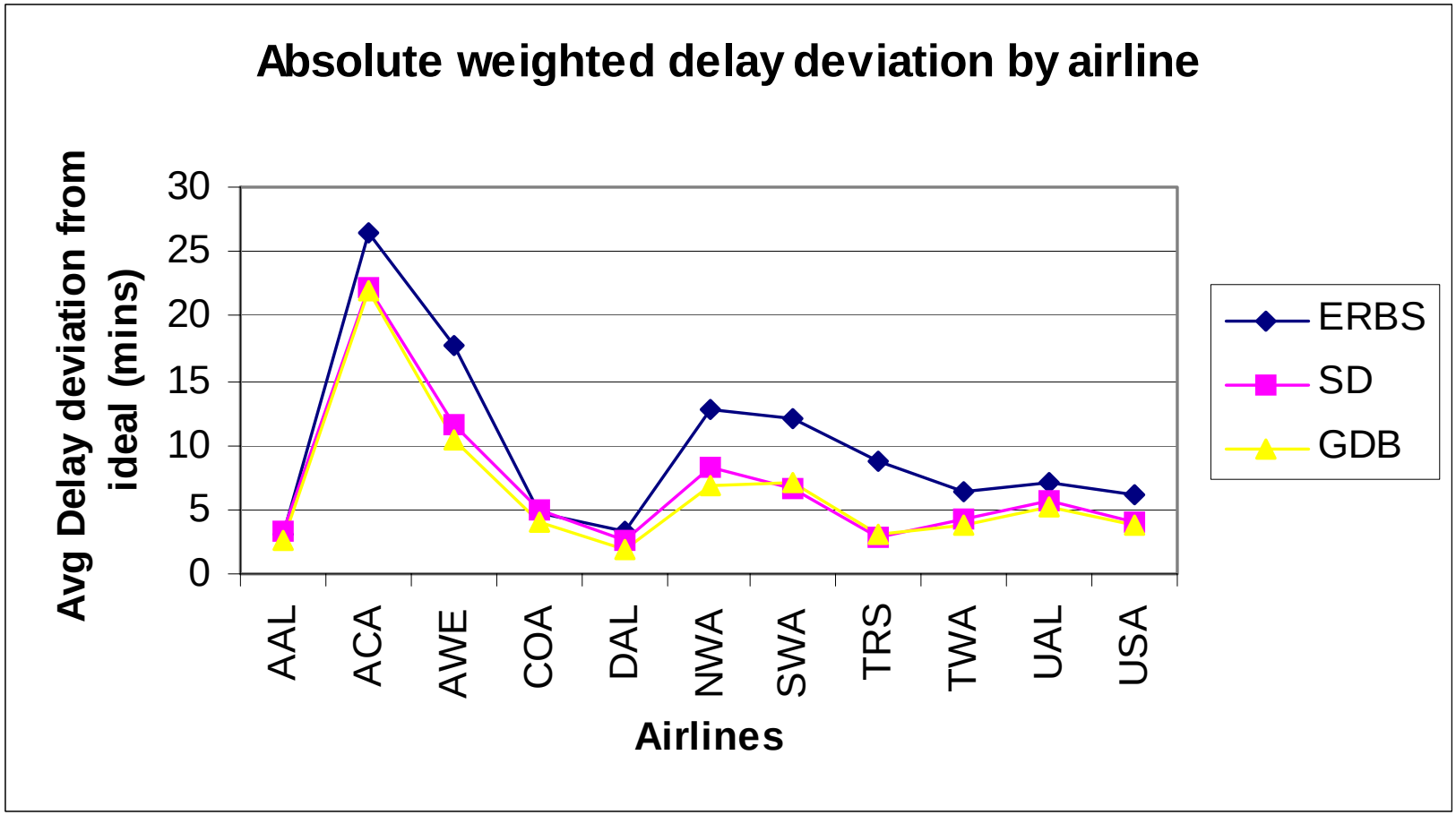
- Is a 2 M minute delay "overage" in 1997 made up for by 1.95 M minute delay "deficit" in 2003??
- Is a 300 minute delay "overage" today made up for by a 305 delay "deficit" tomorrow??
- Answer relates to significance of daily metric vs weekly metric, vs monthly metric vs yearly metric
- Also AEM vs EM – for EM, -300 min in GDP today cancels with +300 min in GDP tomorrow; for AEM both become +300 and they add.

Geographic scope: If a carrier consistently gets too much delay at SFO, is that balanced by too little at BOS?

CDD(c) for 10 largest carriers



CDD'(c) for 10 largest carriers



AEM & EM

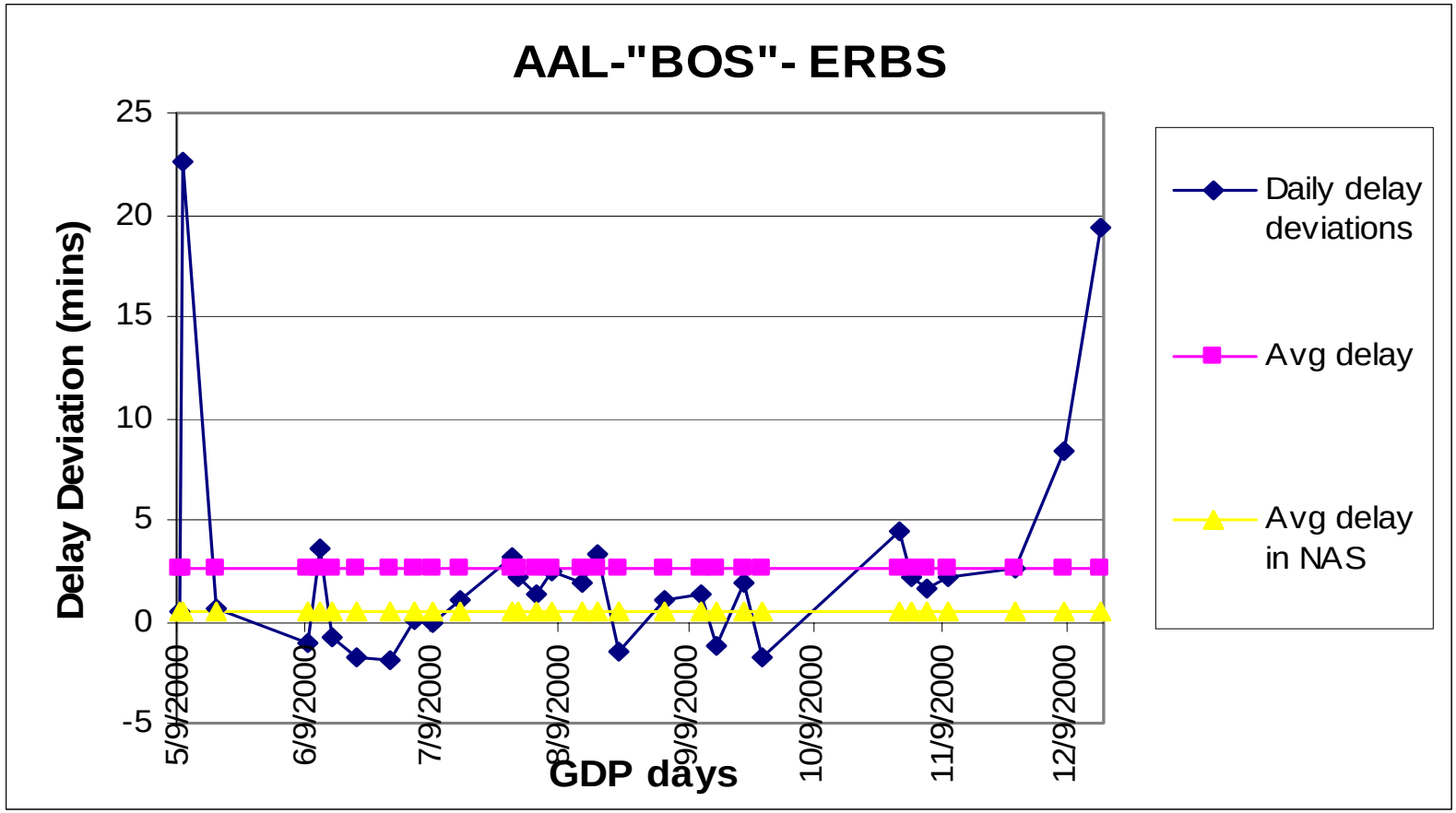
Weighted by number of flights	AEM Carriers > 5000 flts	EM Carriers > 5000 flts	AEM Carriers > 500 flts	EM Carriers > 500 flts
ERBS	6.27	2.90	7.63	3.99
SD	4.89	2.83	6.03	3.91
GDB	4.31	2.53	5.45	3.58

Carriers equally weighted	AEM Carriers > 5000 flts	EM Carriers > 5000 flts	AEM Carriers > 500 flts	EM Carriers > 500 flts
ERBS	9.88	4.64	23.25	17.42
SD	6.95	3.77	19.54	15.70
GDB	6.40	3.57	19.03	15.19

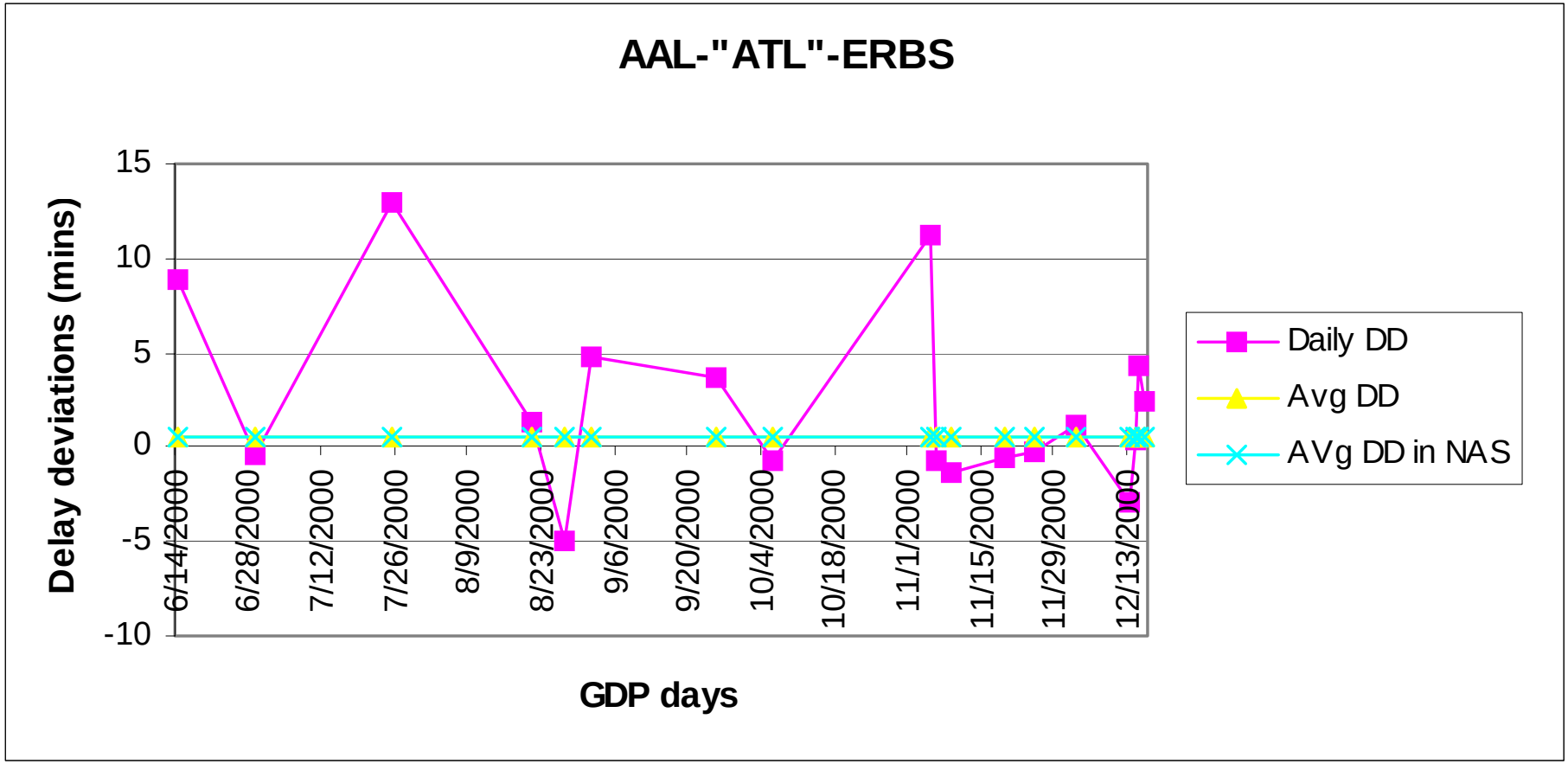
EM vs AEM

Question: to what degree can day-to-day variability in ADD(c,G) be tolerated if “good” days tend to balance out “bad” days??

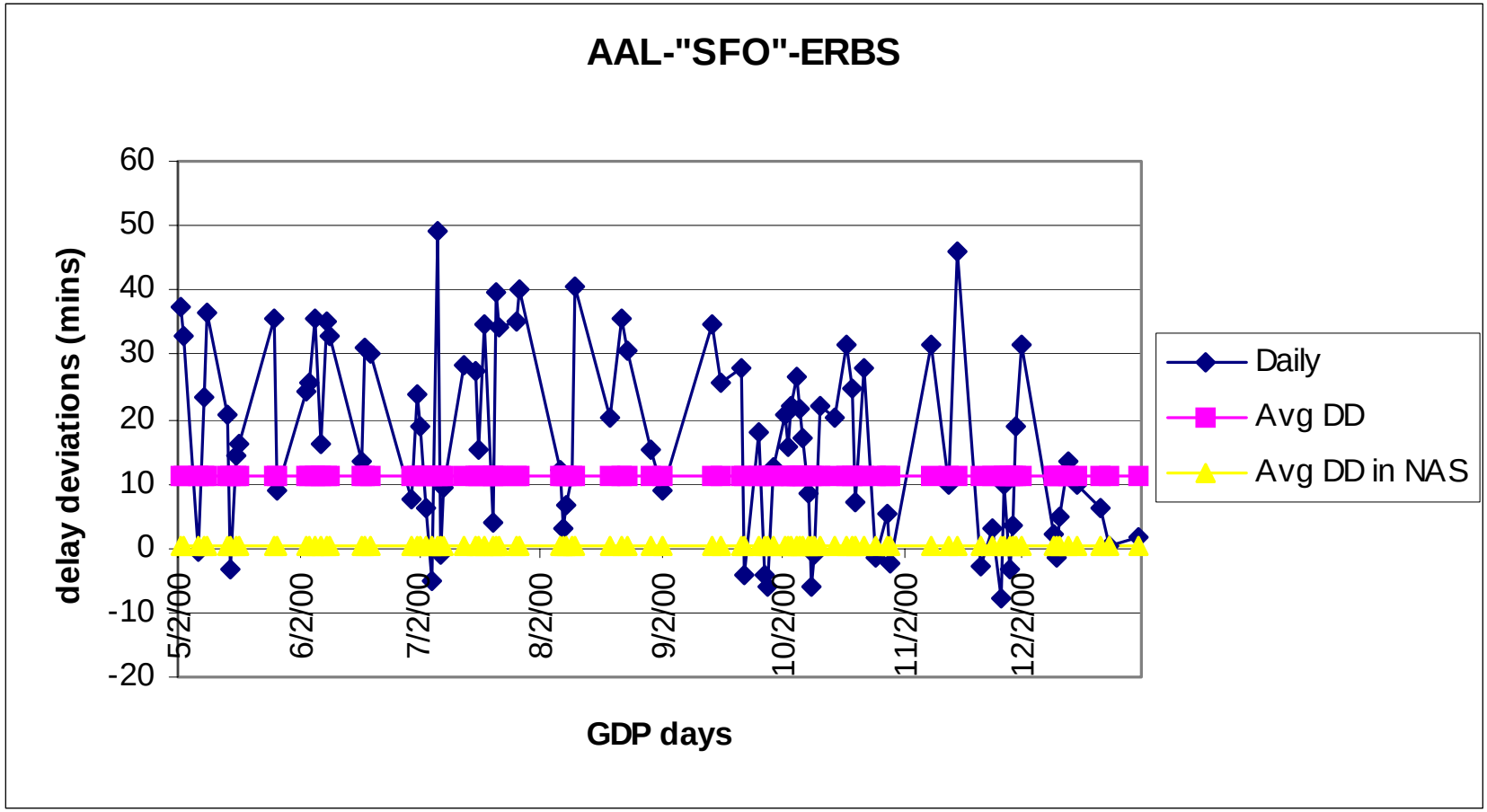
Variability in ADD(c,G)



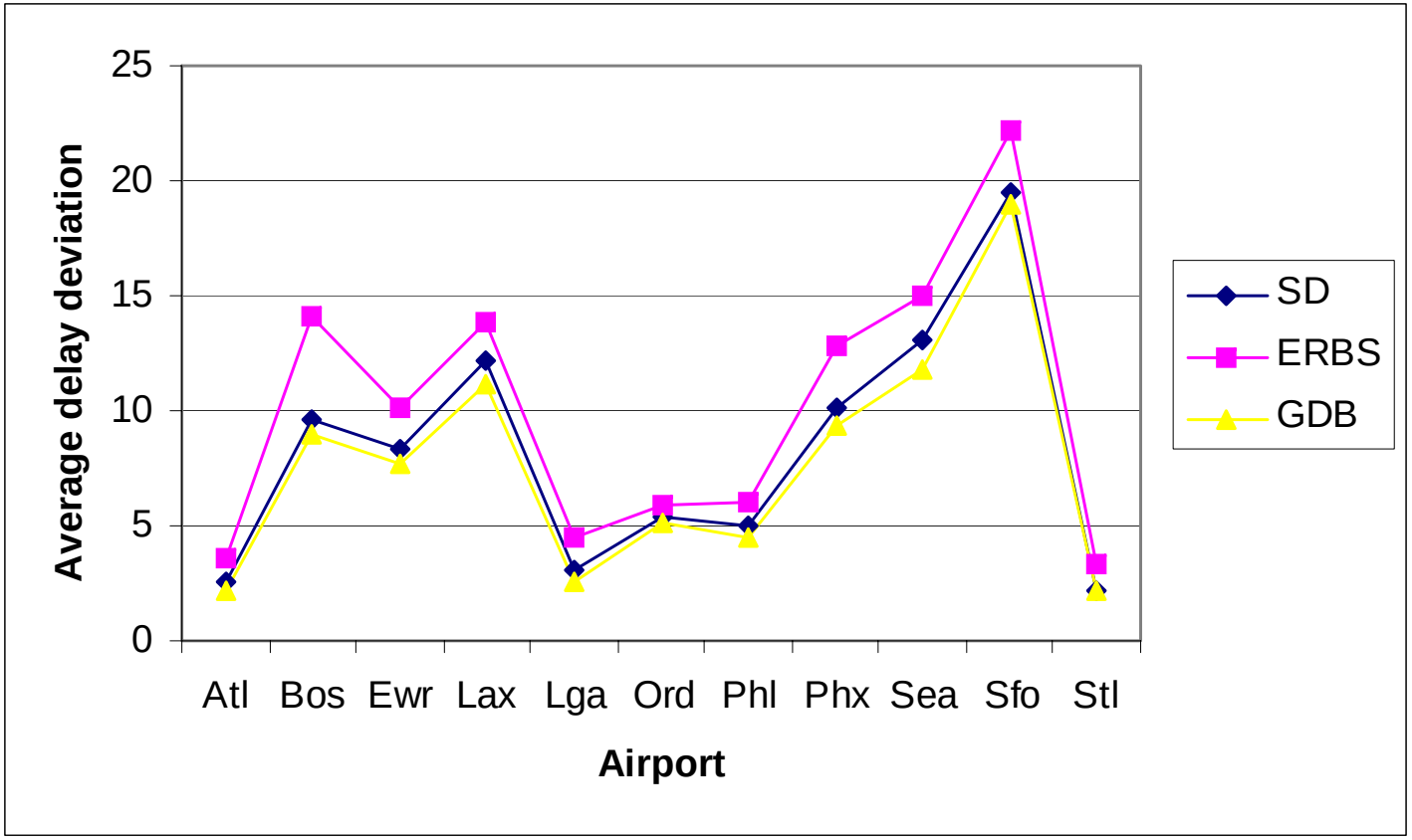
Variability in ADD(c,G)



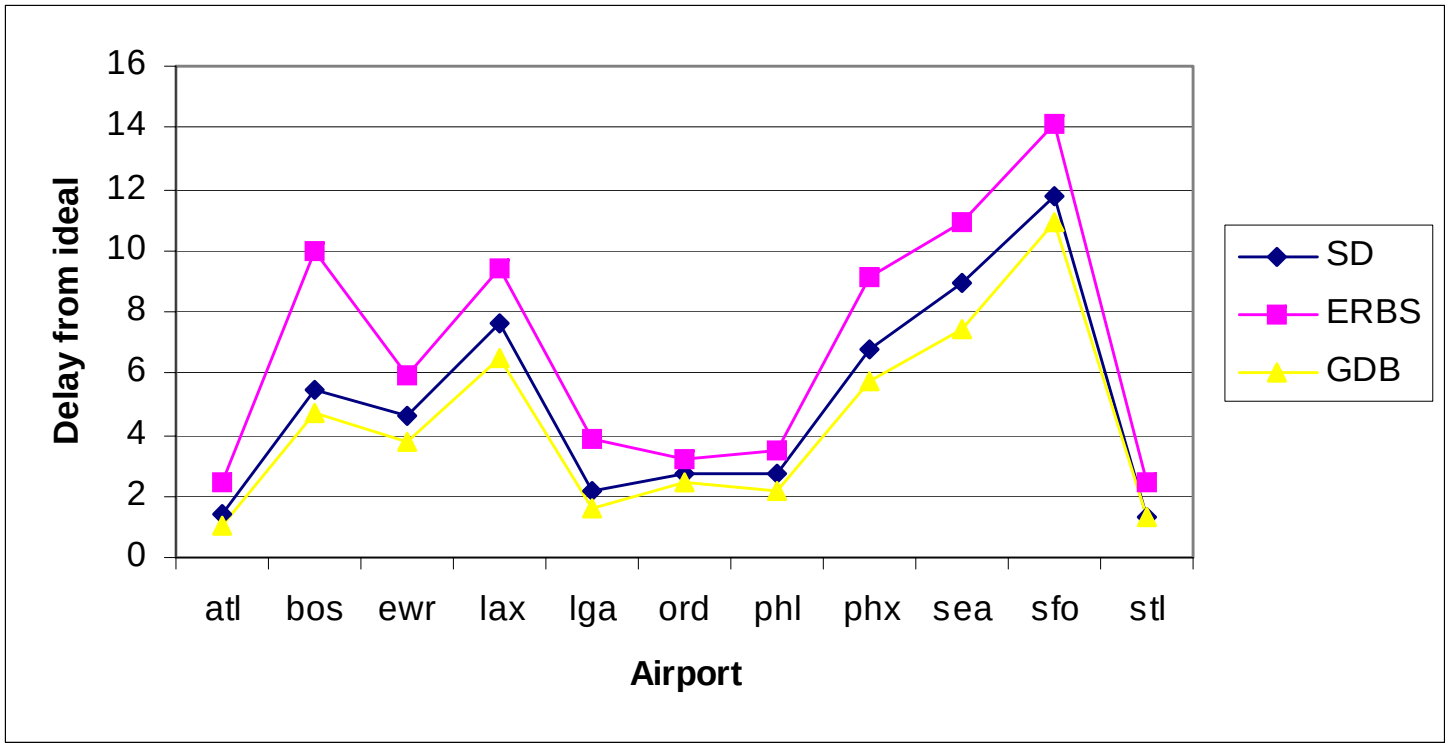
Variability in ADD(c,G)



Airport-Specific Metrics (AEM)

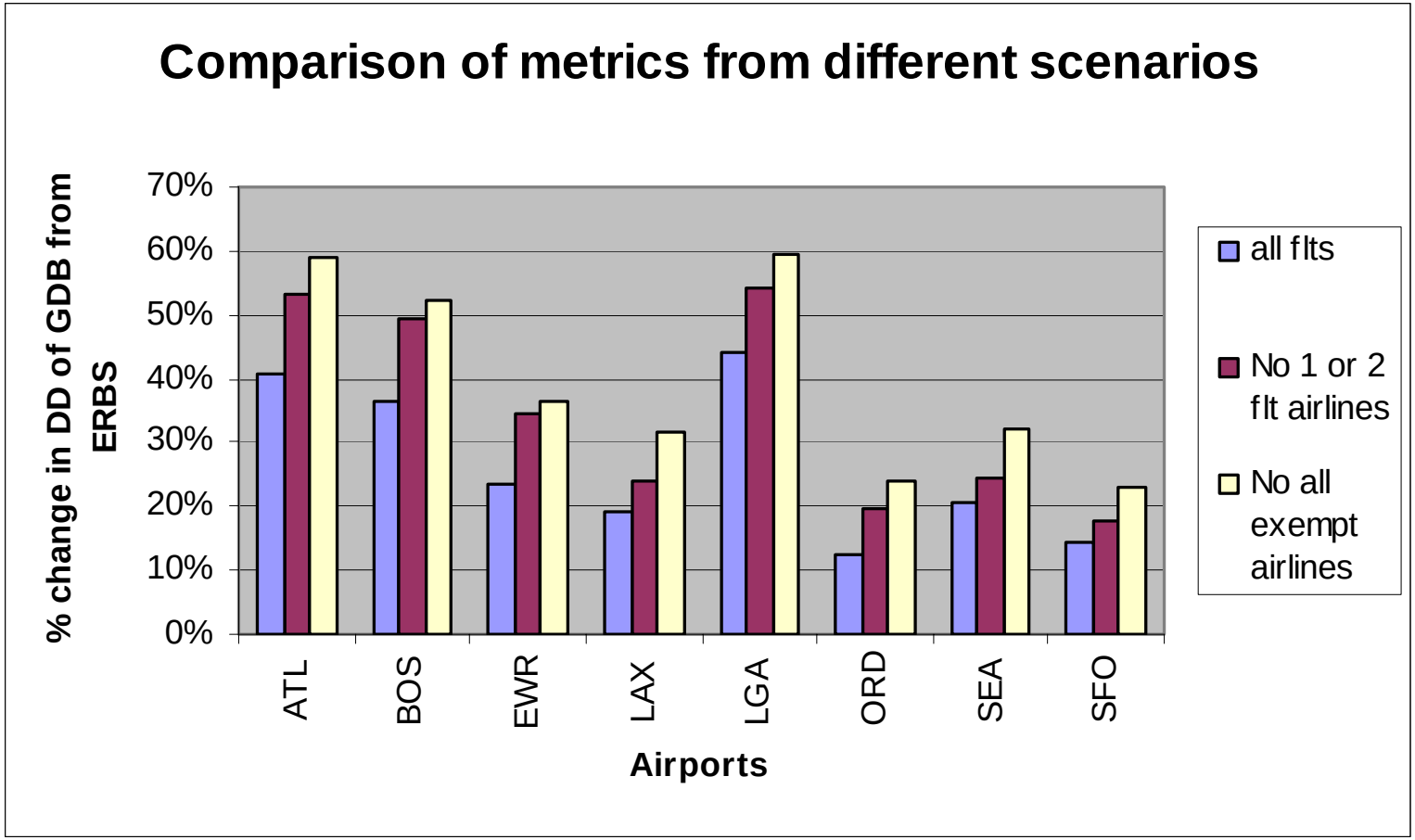


Revised Airport-Specific Metrics (AEM)



Airlines with 1 or 2 flights in a program (usually GA) and airlines with all exempt flights have been deleted

Airport Differences in Ability to Reduce Bias (ERBS vs GDB)



Conclusions and Final Thoughts

Equity Principle: metric = measure of deviation between actual and ideal allocation

Scope issues (geographic and temporal):

- While, to a degree, a delay deficit at one airport can be balanced out by a delay surplus at another, a carrier's ability to compete in a given market could be eroded by systematic bias at a given airport → airport-specific metrics have value
- Over shorter time frames temporal balancing clearly is effective at balancing equity, but over longer time frames it may not be; it is also the case that large day-to-day variation should be reduced if possible

Definition of ideal:

- For GDPs, RBS has strong merits but other ideas are worth consideration
- Enroute -- ???