

Free Flight En Route Metrics

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The Free Flight Metrics Team



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 - **NEXTOR, Northrup/Grumman, MITRE/CAASD, RPI, Aerospace**



What we do



- **Free Flight Tools**
 - URET
 - TMA
 - CPDLC
 - CDM
- **Estimate potential benefits pool**
- **Future benefits projection**
 - Investment Analyses
 - OMB Exhibit 300
- **Post-implementation measurement of impact**



En Route Metrics



Tie projected benefits to observable metrics



Observed Modeled

	Observed	Modeled
Excess distance (compared to great circle) ➤ <i>Primary metric for en route</i>		
Flight times Wind-adjusted		
Excess distance and flight time by phase of flight “Lines data”		
Flight Plan Amendments Distance savings from amendments		
En Route Throughput “Hoses data”		
Delay Ground, Airborne		



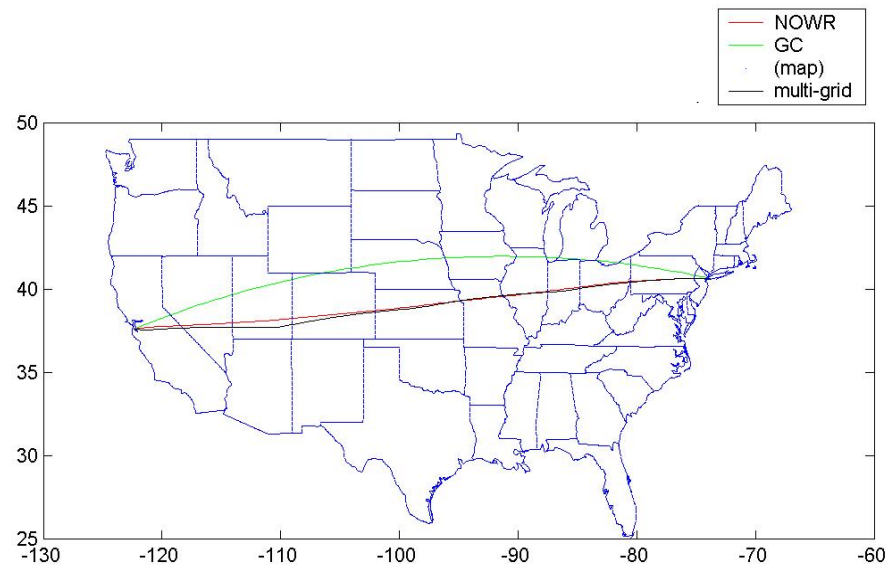
What about Wind-Optimal?



- **Wind-optimal is the most efficient trajectory**
 - Computationally intensive
 - Availability of wind data
 - Moving target
- **Are great circle routes a good proxy for wind-optimal?**

Compare:
Actual Route
Wind-Optimal
Great Circle
(Exclude within 50
miles of airports)

For all flights on
two sample days



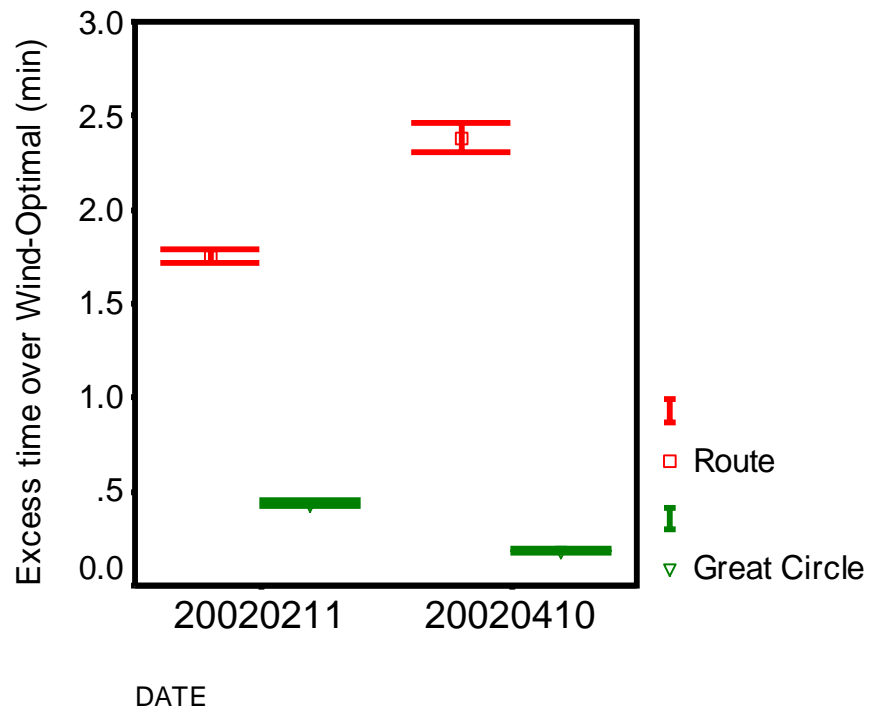
Source: J. Bonn



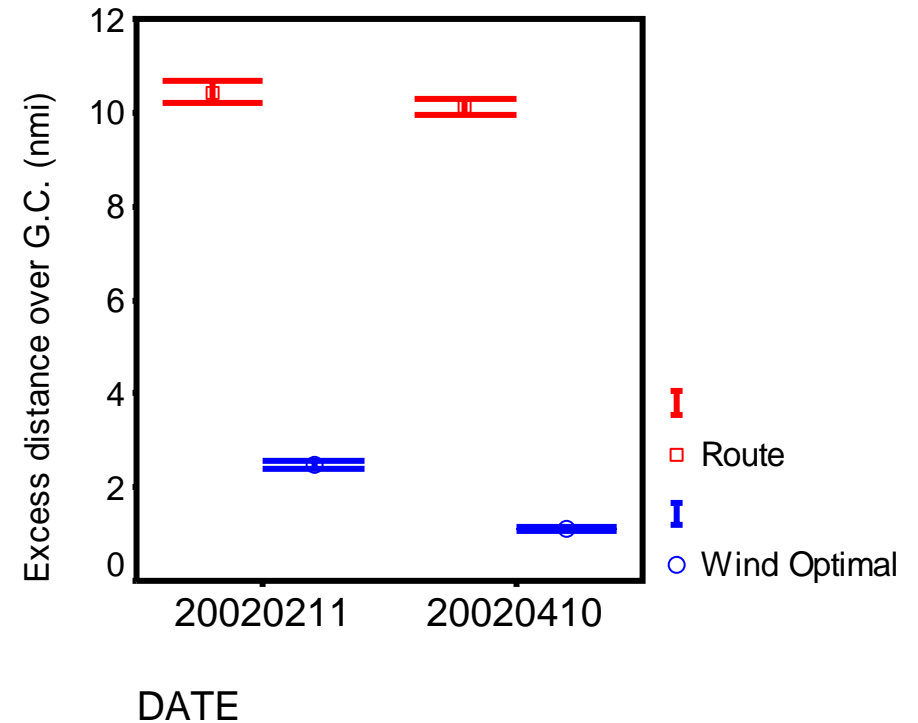
Actual vs. Idealized Trajectories



Time



Distance



***When considering improvements to actual routes,
In the mean, Great Circles are a good proxy for wind-optimal***

***Potential Benefits Pool: 370,000 nmi per day
Is all of that pool recoverable?***

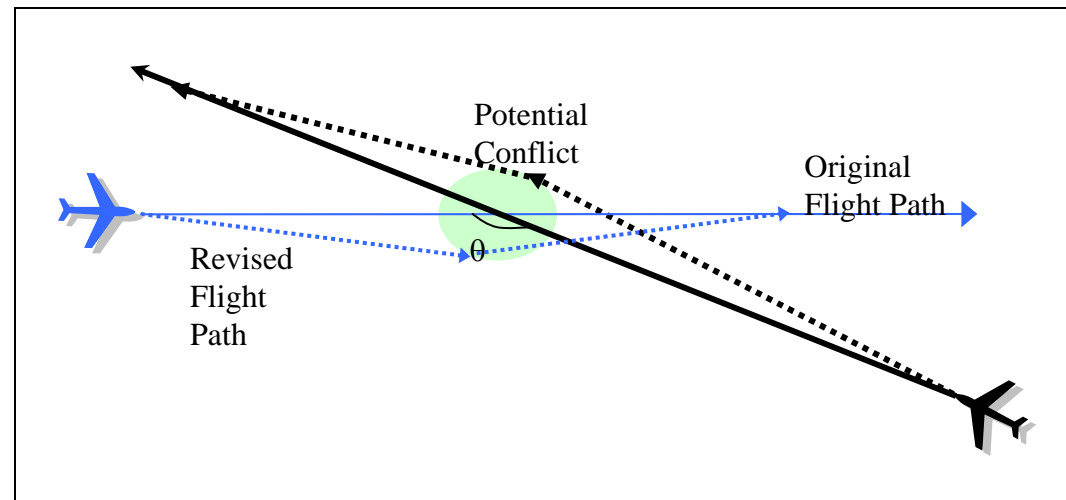


Benefits Pool with Conflicts



- Use FACET to identify conflicts and provide geometry and aircraft speeds

For sample day,
0.47 conflicts / flight



- Numerically solve for minimum conflict cost

Buffer	Cost of Conflict	Pool Reduction	Adjusted Pool
5 nmi	1.4 nmi	6%	310K nmi/day (\$700M/yr)
10 nmi	3.6 nmi	16%	345K nmi/day (\$790M/yr)

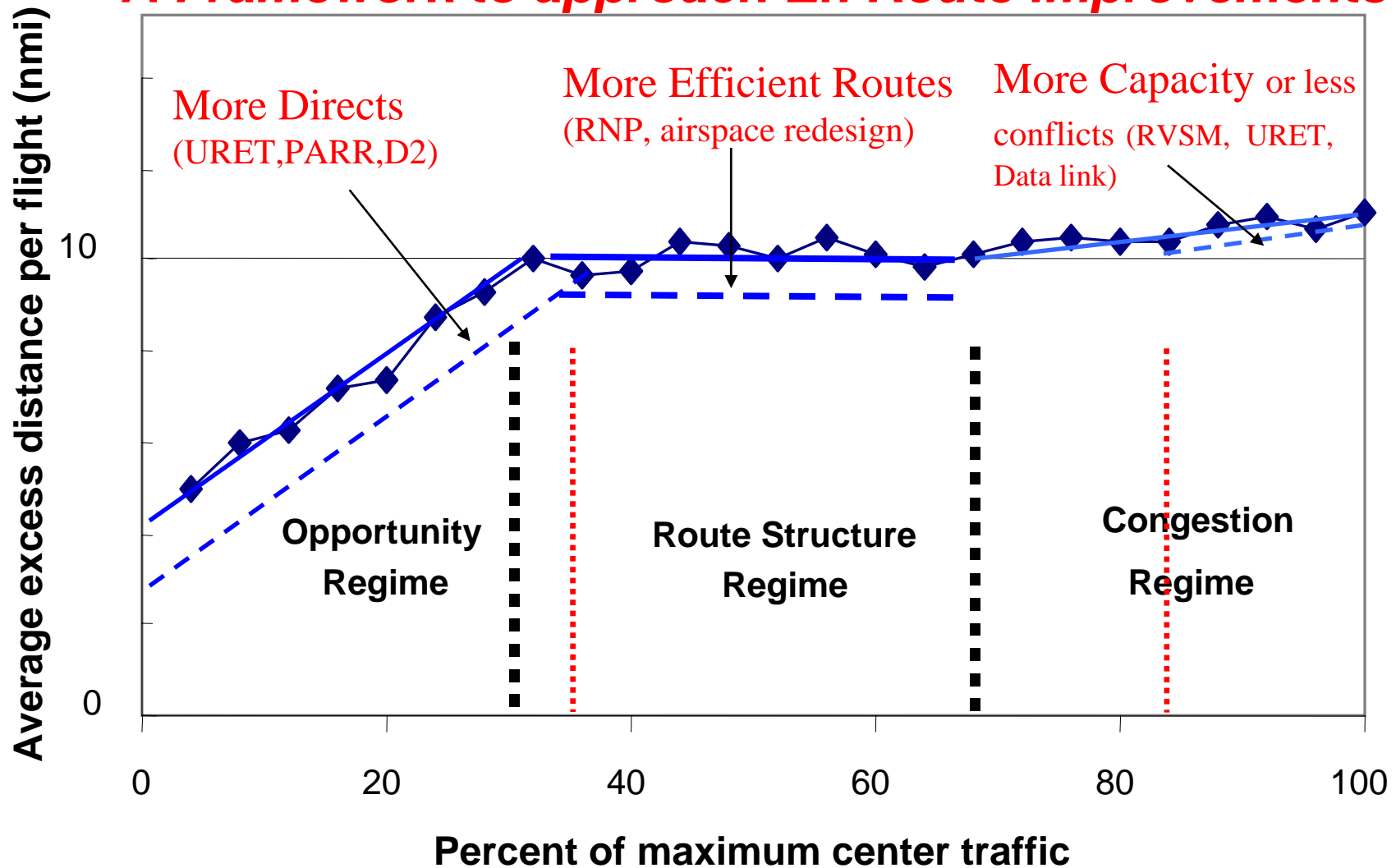
Source: D. Howell, J. Bonn



Excess distance and traffic load



A Framework to approach En Route Improvements

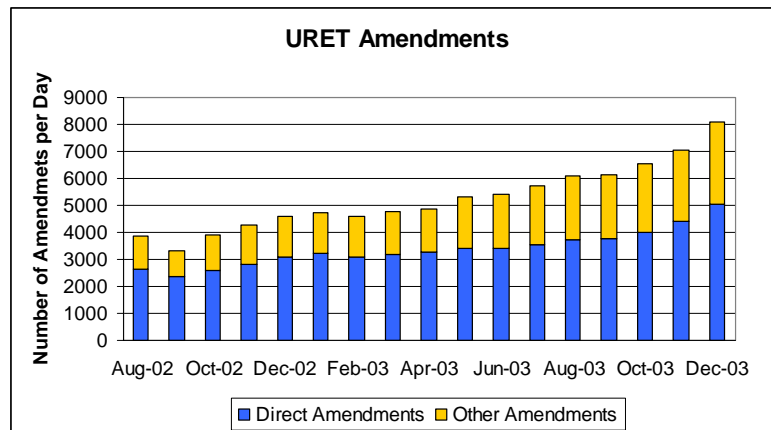




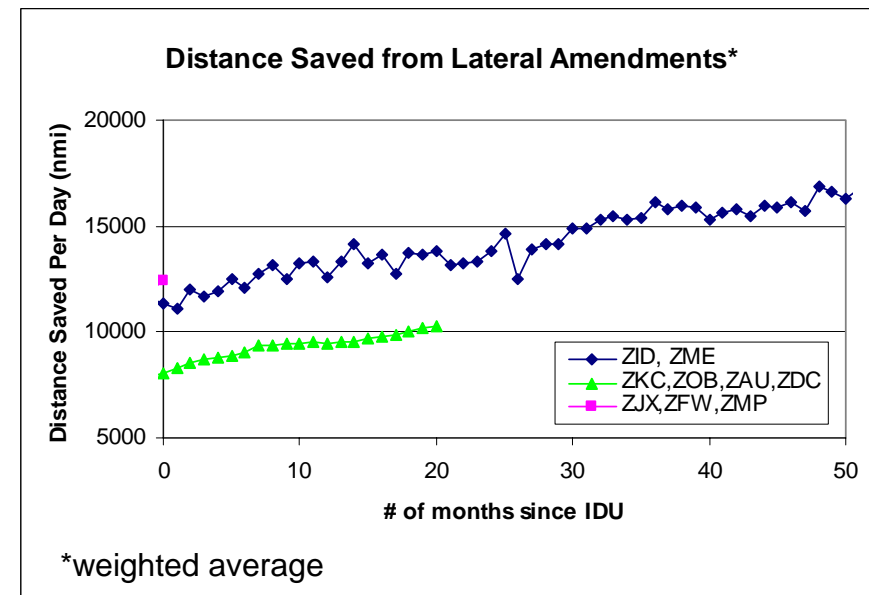
Distance Saved from Lateral Amendments



- **As URET is deployed, we track**
 - Number of flight plan amendments
 - Distance savings from lateral amendments
- **Periodically update benefits estimates**
 - Free Flight Reports, OMB Exhibit 300



Source: D. Murphy





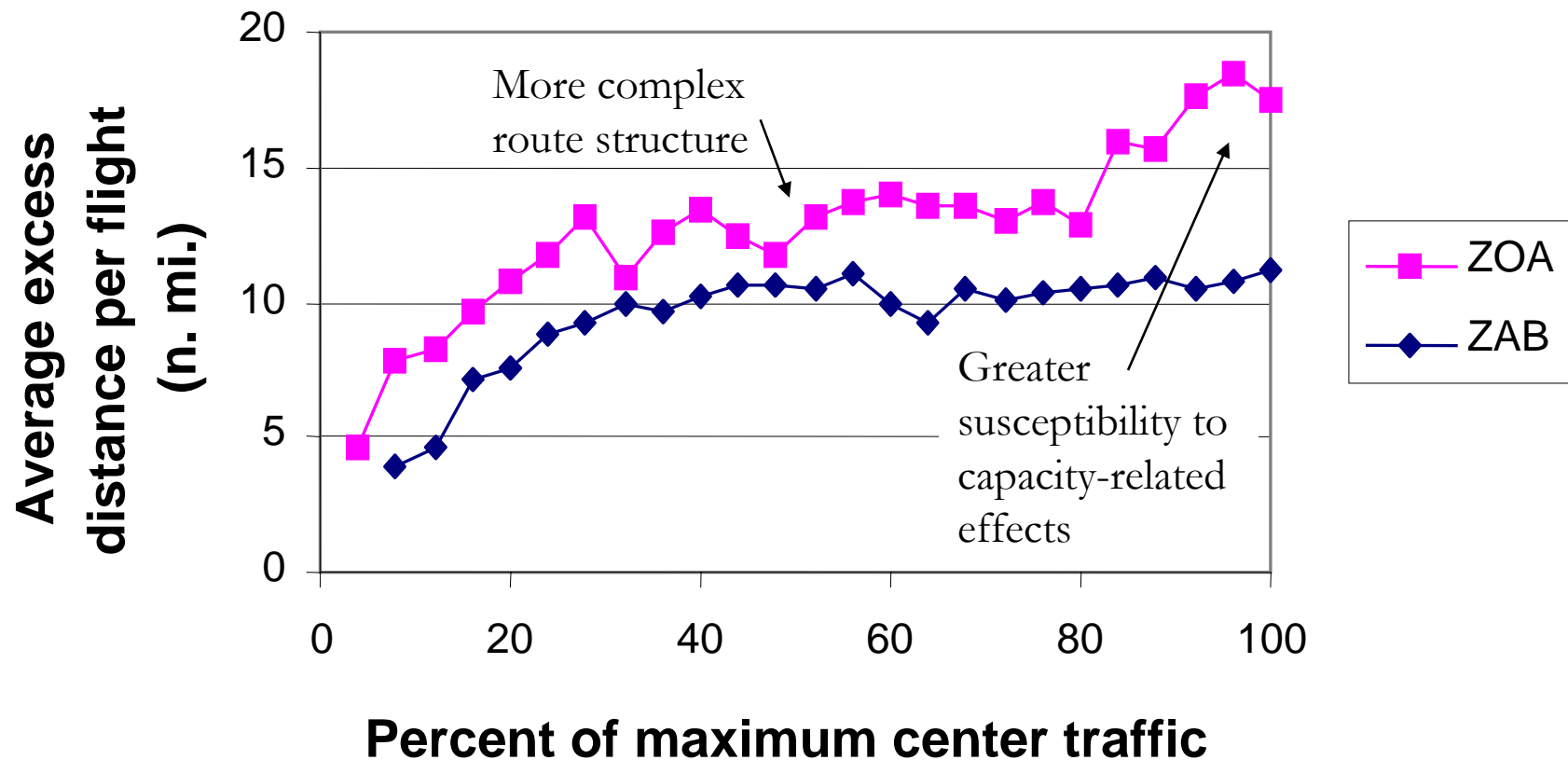
Excess distance vs. traffic load by center



Important to establish site-specific baselines

ZOA - has higher traffic levels

- handles a higher proportion of arrivals and departures than ZAB

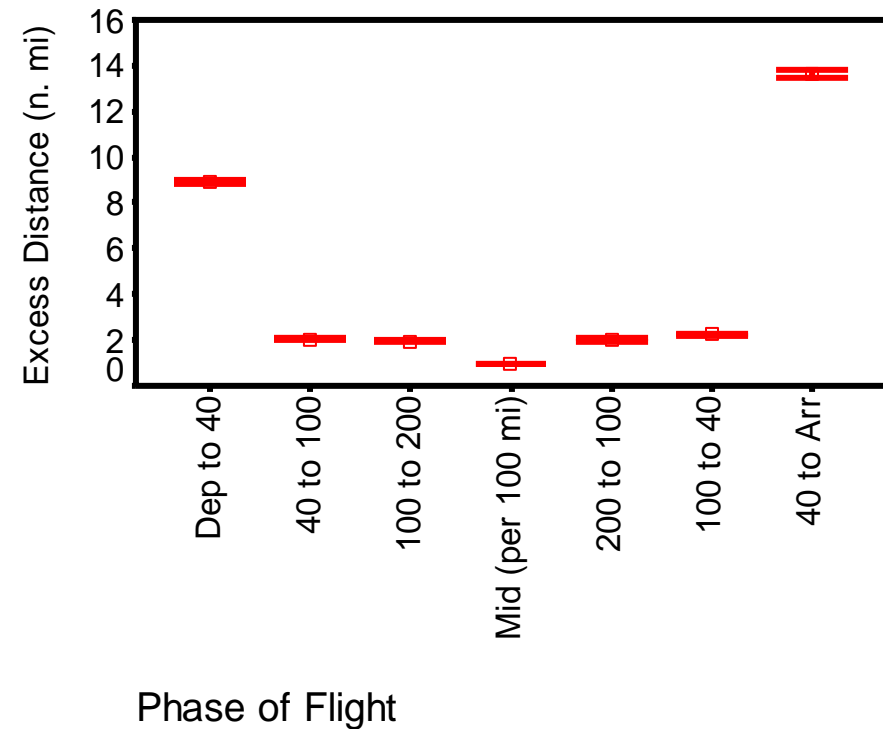
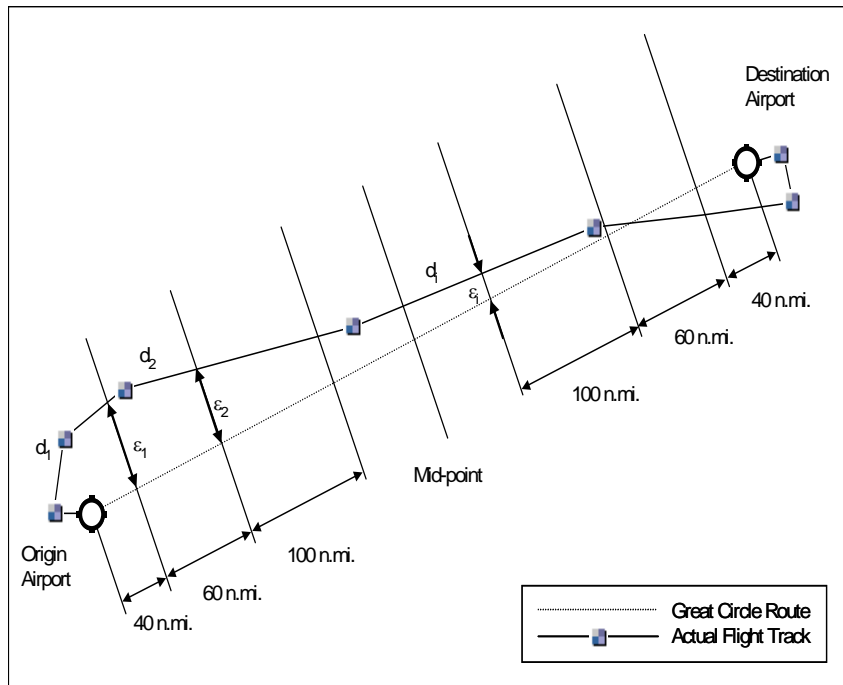




Efficiency by Phase of Flight



- Break up flight into segments
- Track excess distance, flight time, degrees turned
 - Algorithm developed and coded at Free Flight
 - ATALAB generated archive for all flights since 1998
 - Subset available in ASPM

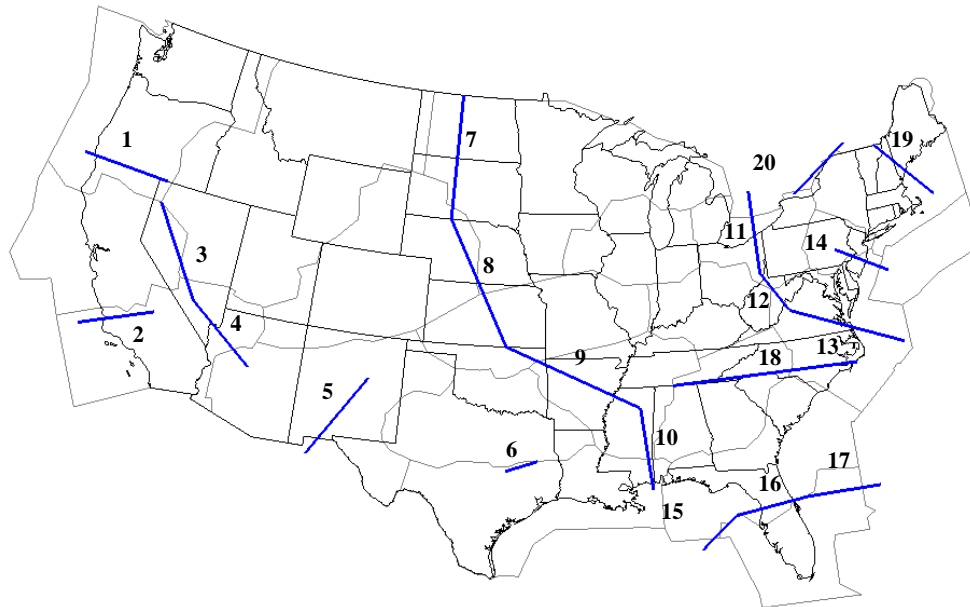




En Route Throughput



- **Construct throughput lines (“hoses”) that capture major traffic flows**
- **Measure throughput over lines**
 - Also track crossing time and position by flight
- **Algorithm developed by Free Flight and OEP**
 - Coded at Free Flight
 - ATALAB generated archive for all flights since 1998

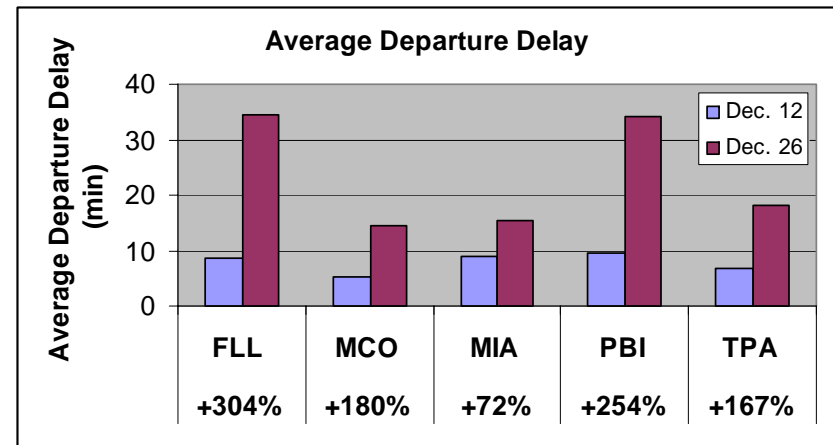
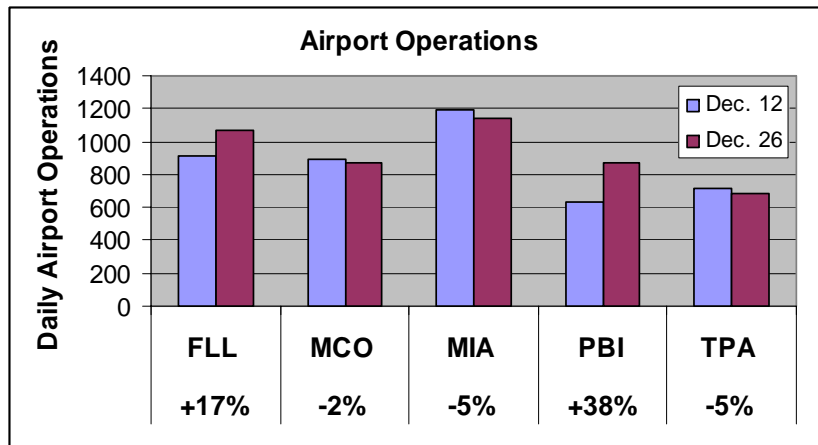
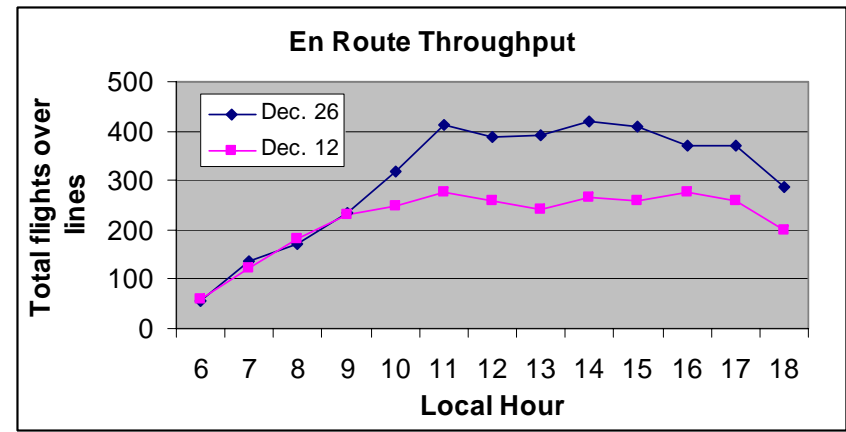
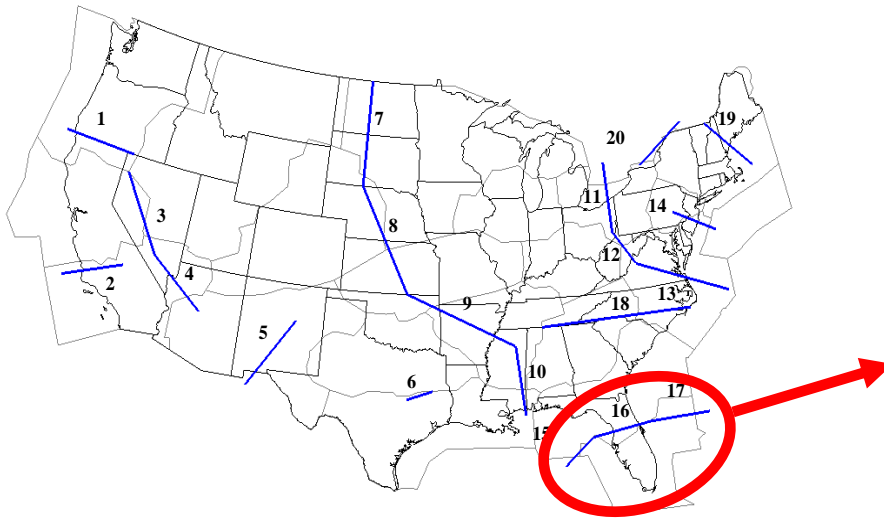




En Route Throughput and Departure Delay



Look at impact of holiday flights in ZMA





Need for Better En Route Models



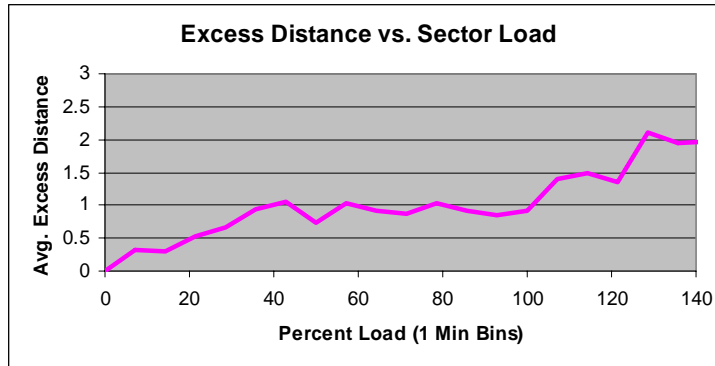
- **En Route problems manifest themselves in several ways**
 - Excess distance, departure delay, MIT, Ground stops
- **Difficult to separate en route problems from terminal effects**
- **Current queuing models have shortcomings**
 - Don't deal well with all constraints
 - **TRACON capacity**
 - No modeling of airspace performance when demand < capacity
 - **No “Opportunity” regime**
 - Trajectories are non-adaptive
 - **Tactical (Local congestion, weather)**
 - **Strategic (TFM)**



Here's what we'd like to see a model do...



Modeling Airspace Performance



If sector load < capacity,
Adjust dwell time stochastically

Modeled aircraft approaches
new sector

If sector load > capacity,

- Allow to enter and adjust dwell time, OR
- Delay

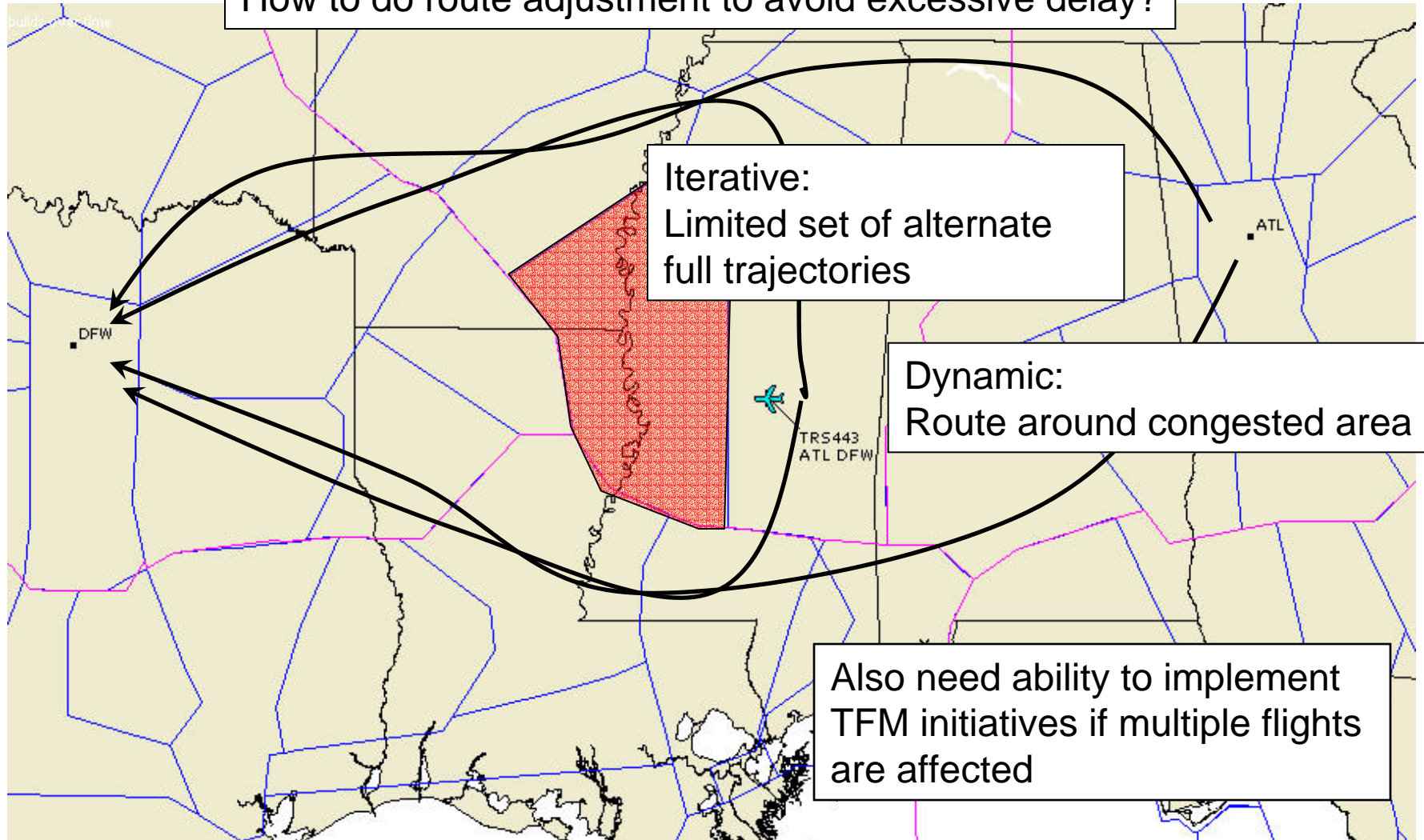
If delay is excessive, adjust trajectory—
HOW???



Modeling Airspace Performance



How to do route adjustment to avoid excessive delay?





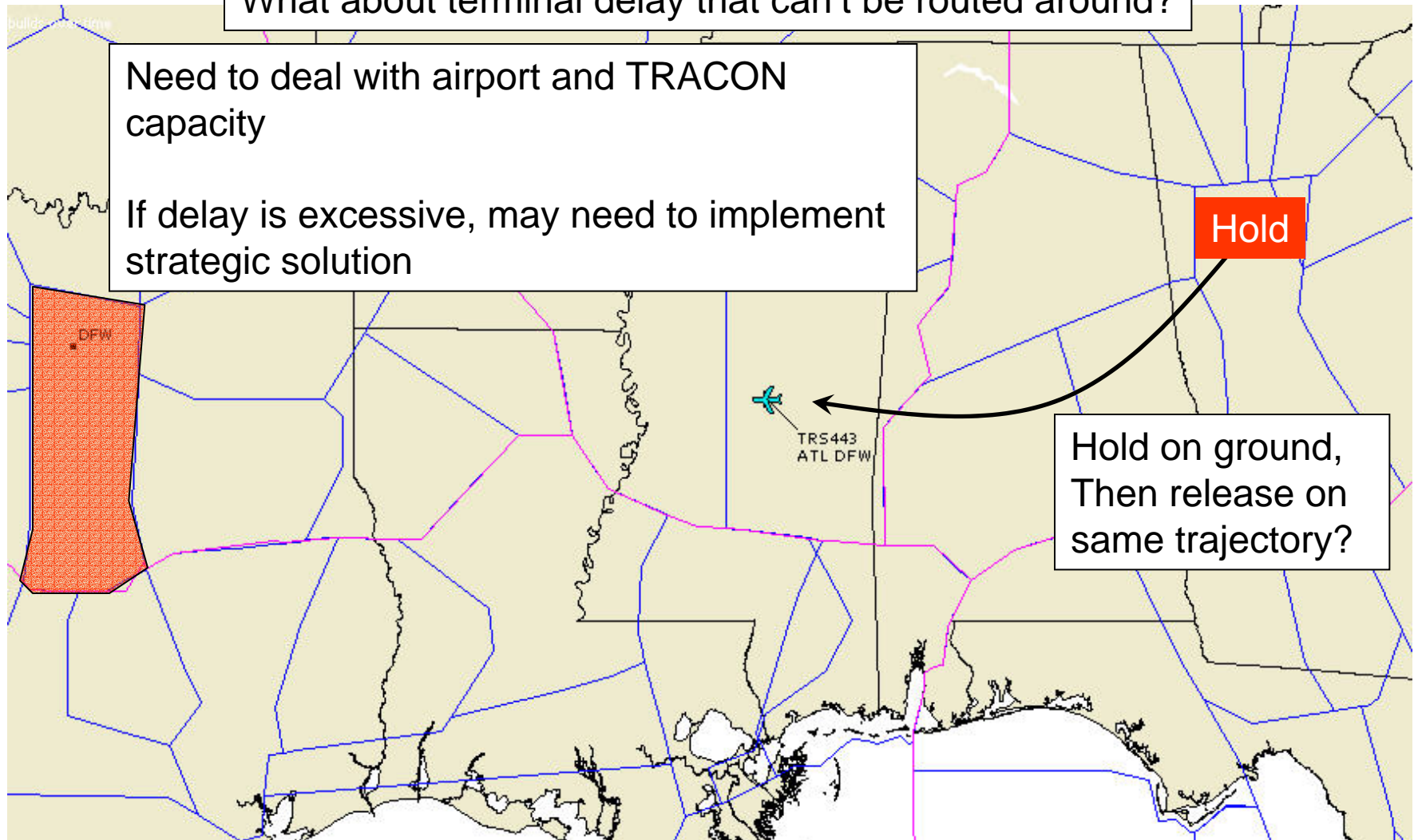
Modeling Airspace Performance



What about terminal delay that can't be routed around?

Need to deal with airport and TRACON capacity

If delay is excessive, may need to implement strategic solution



Hold on ground,
Then release on
same trajectory?



Summary



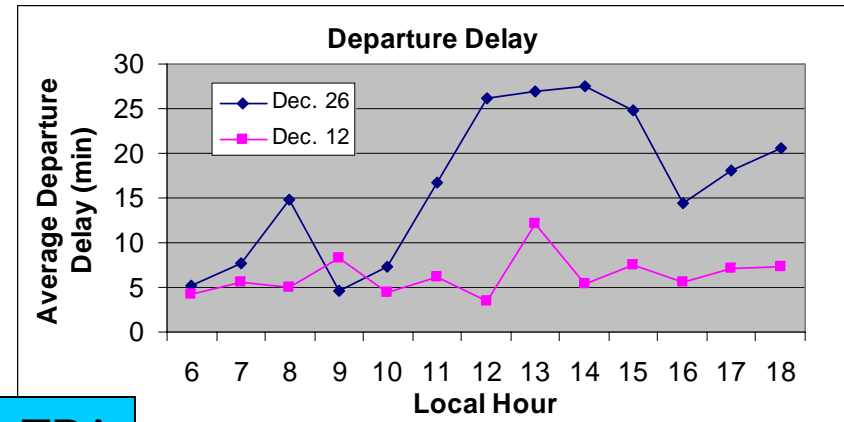
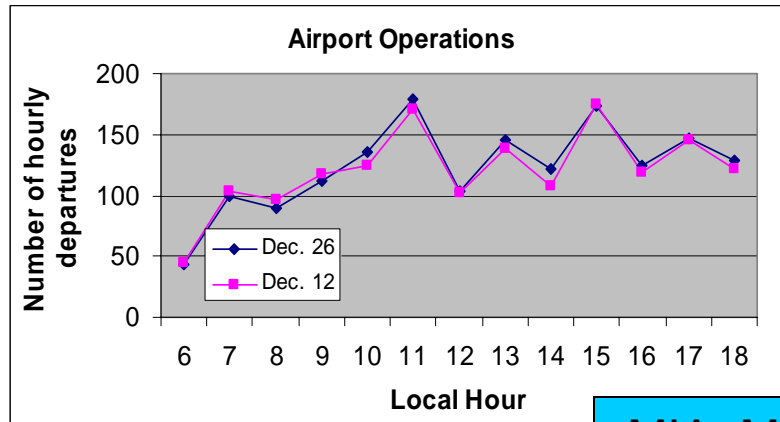
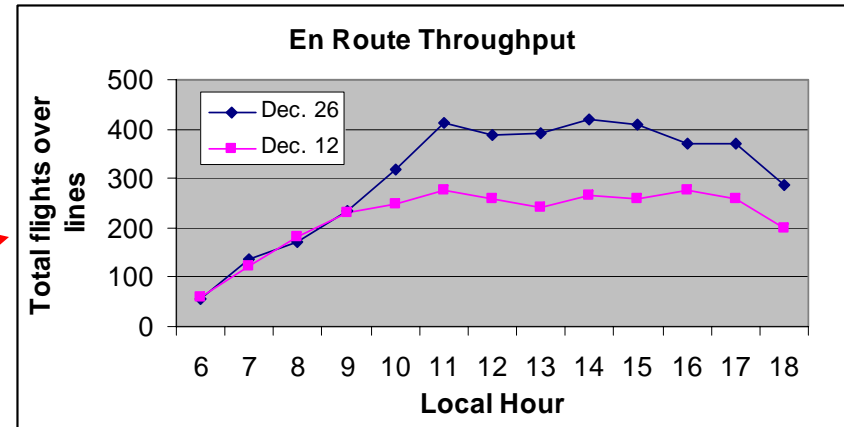
- **Free Flight uses several en route metrics**
 - Projections of future benefits
 - Assessment of deployed tools
- **Our approach**
 - Need to understand magnitude of problem (size of pool)
 - Tie projected benefits to observable metrics
 - Establish site-specific metrics baselines
- **Need better en route models**



Questions?



En Route Throughput and Departure Delay



MIA, MCO, TPA

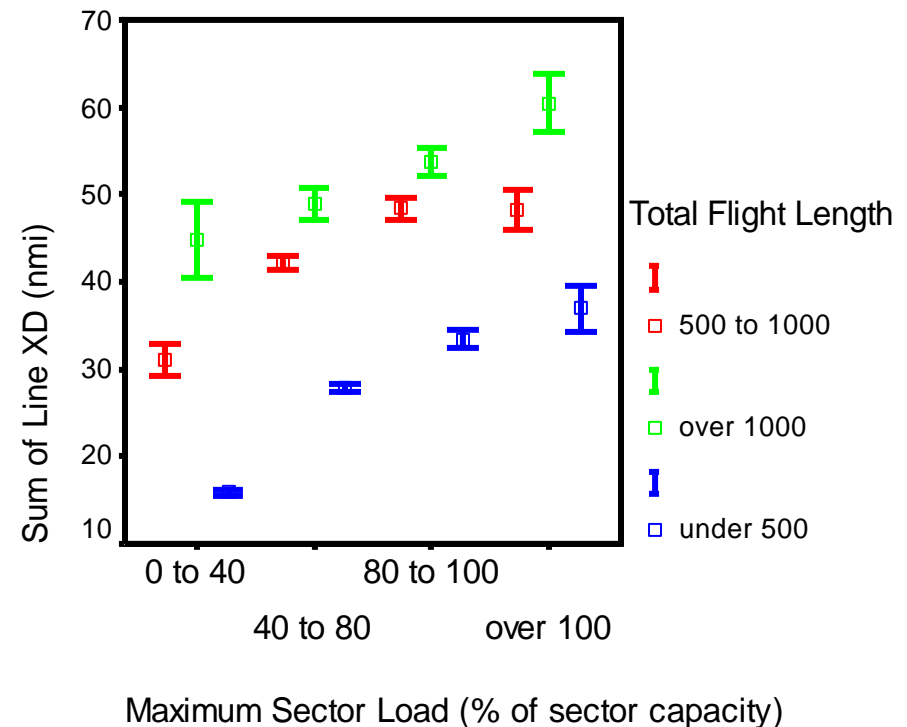


Impact of Sector Capacity



- Use line data to look at excess distance for flights encountering busy sectors

Encountering a single busy sector seriously affects excess distance

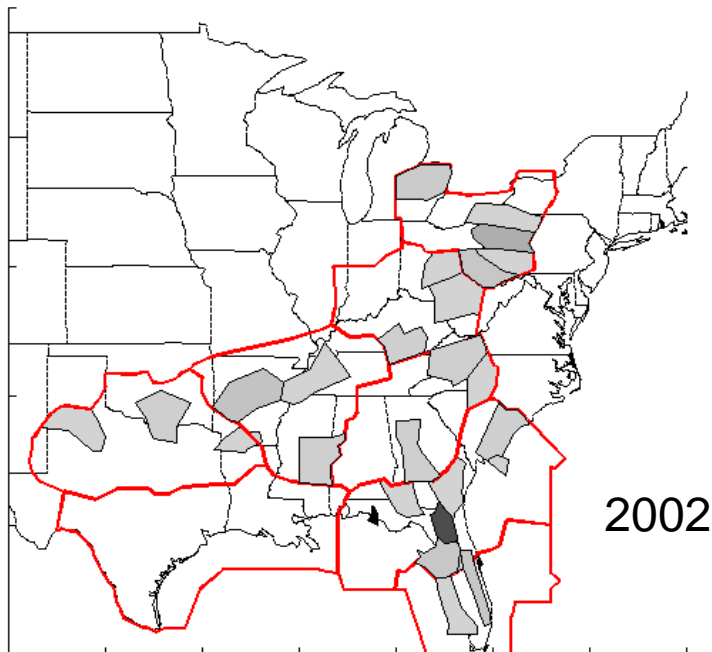




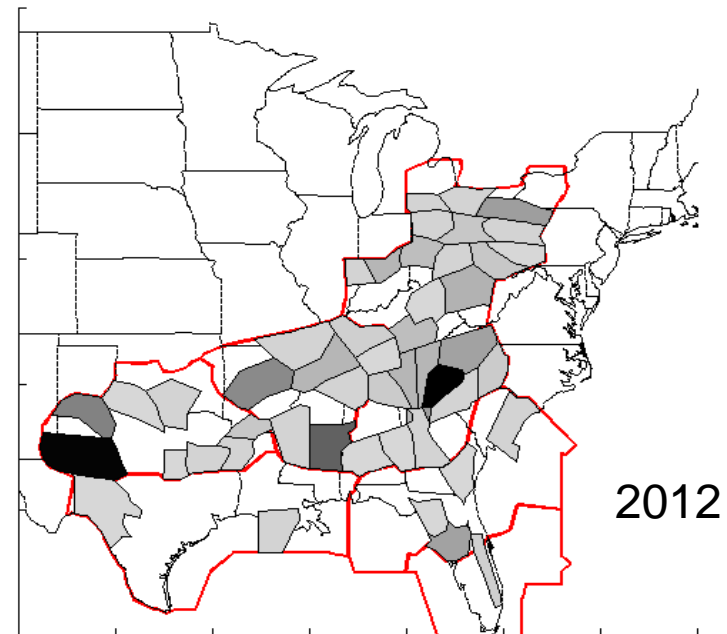
Modeled Sector En Route Daily Delay



High Sectors



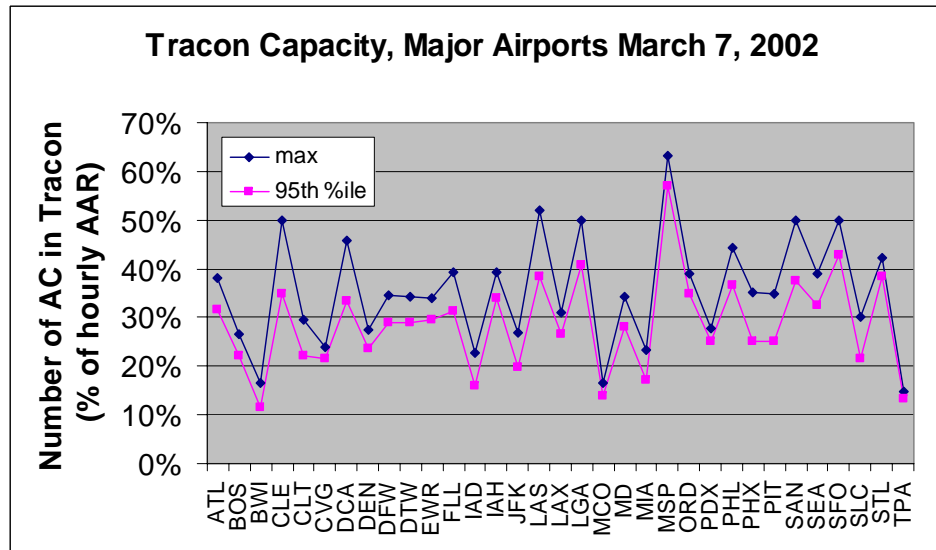
Many en route sectors are currently capacity constrained



Capacity constraints in en route airspace will become more of a problem in the future



Implementing TRACON capacity



Average of 95th percentile:
29%

