Lessons Learned from FAA Free Flight's En Route Modeling Workshop

with a CPDLC Modeling Case Study

Dave Knorr & Mike Bennett

FAA Free Flight Office

4 November, 2003

Need for En Route Modeling

- **Future demand will begin to increase delays related to en route sector capacity constraints**
- **Need capability to assess the magnitude of the en route problem**
- **Need modeling to compare the System level value of alternative solutions (datalink vs. ERAM vs. airspace redesign vs. XXX)**
- **Need to be able to develop credible $$ benefit projections**

En Route Modeling Workshop Overview

- **FAA Free Flight Office held a modeling workshop in March of 2003**
- **Goals were:**
  - **understand modeling options for en route sector capacity increases**
  - **Insight into consistency of model results**
  - **Assess FACET as potential model engine**
- **Attendees**
  - **Boeing, NASA, CENA, Mitre CAASD, LMI, Metron, SAIC, CSSI, Aerospace, NEXTOR, FAA Tech Center, etc.**

Modeling Workshop Findings

- No single model met all of the needs
- List of functionalities of models
- No understanding of the relative validity of results
- Need for establishing a standardized set of inputs for model comparisons

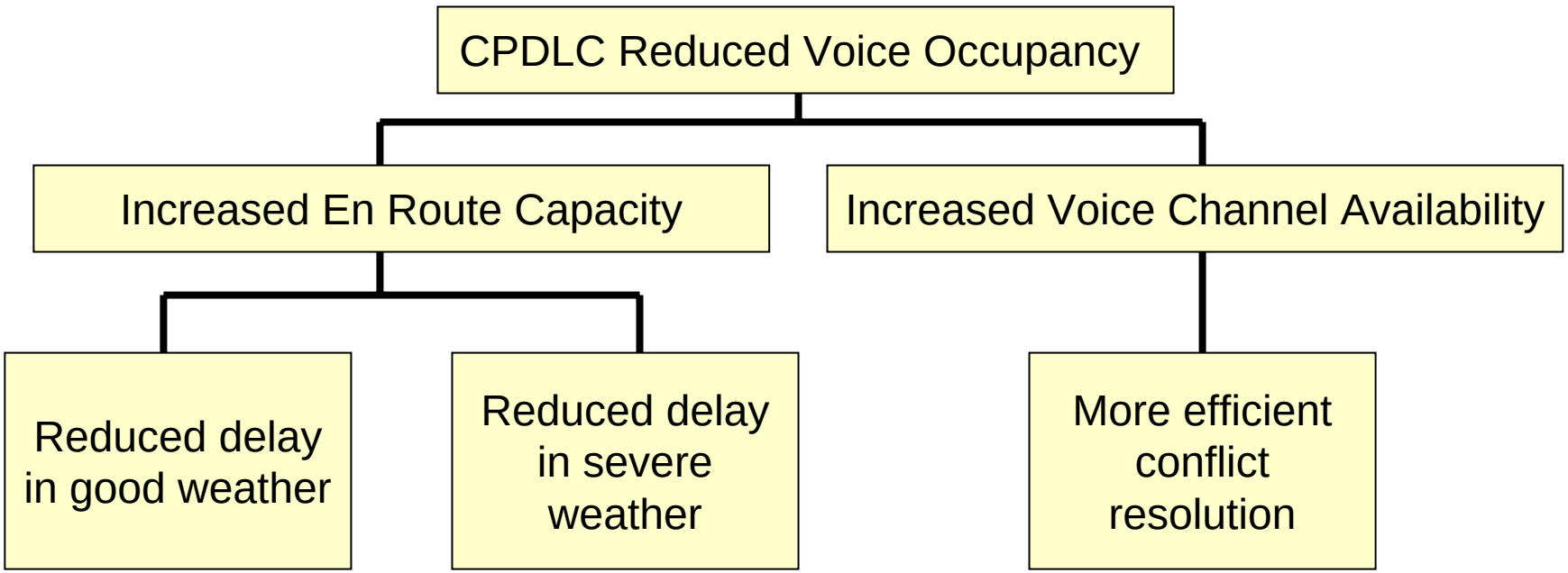
What should a model include? A case study

- From a user's perspective, what capabilities should a model have?
- What a model needs to do:
  - Quantify benefits of tool to airspace user
    - Delay reduction, fuel savings
  - Estimate benefits over lifetime of tool (10 years)
    - Breakdown by Center, by Year
- Consider Controller-Pilot Data Link Communications (CPDLC) Investment Analysis as a case study

Controller Pilot Data Link Communications (CPDLC)

CPDLC Benefit Analysis Steps

- **Determine Workload impact of CPDLC**
  - **Performed with voice tape analysis, HITL simulation**
- **Estimate Sector Capacity Increase (High vs. Low Sectors)**
- **Model decrease in delay associated with**
  - **capacity increase**
  - **increased trajectory efficiency**

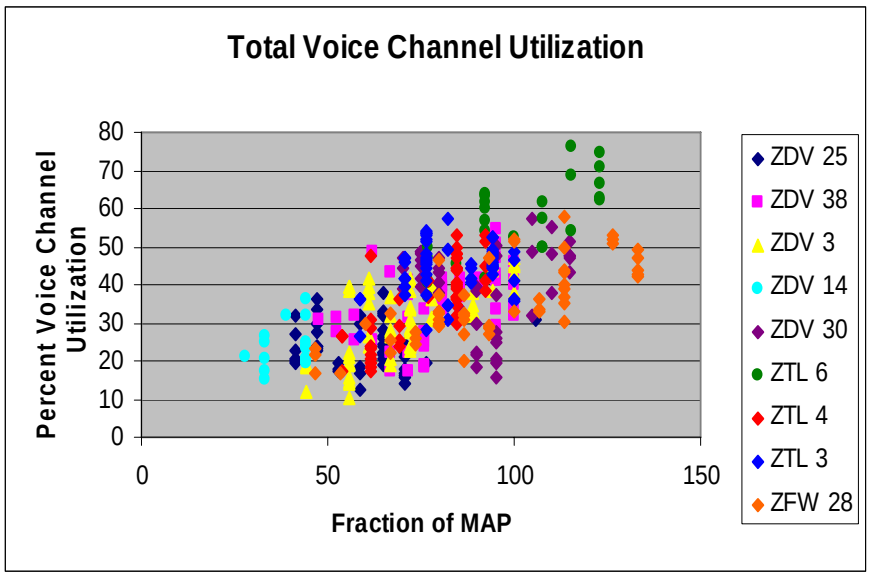


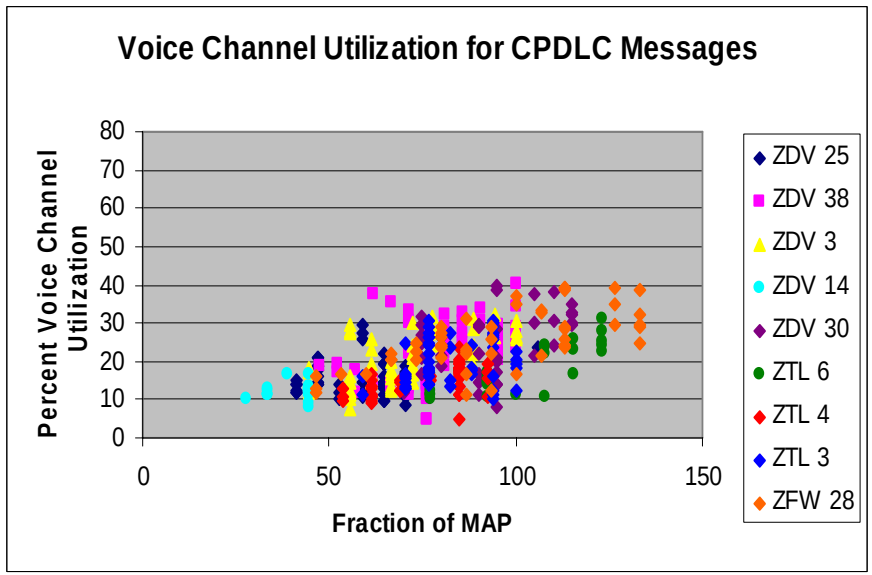
NASPAC & DPAT

CSSI TTT

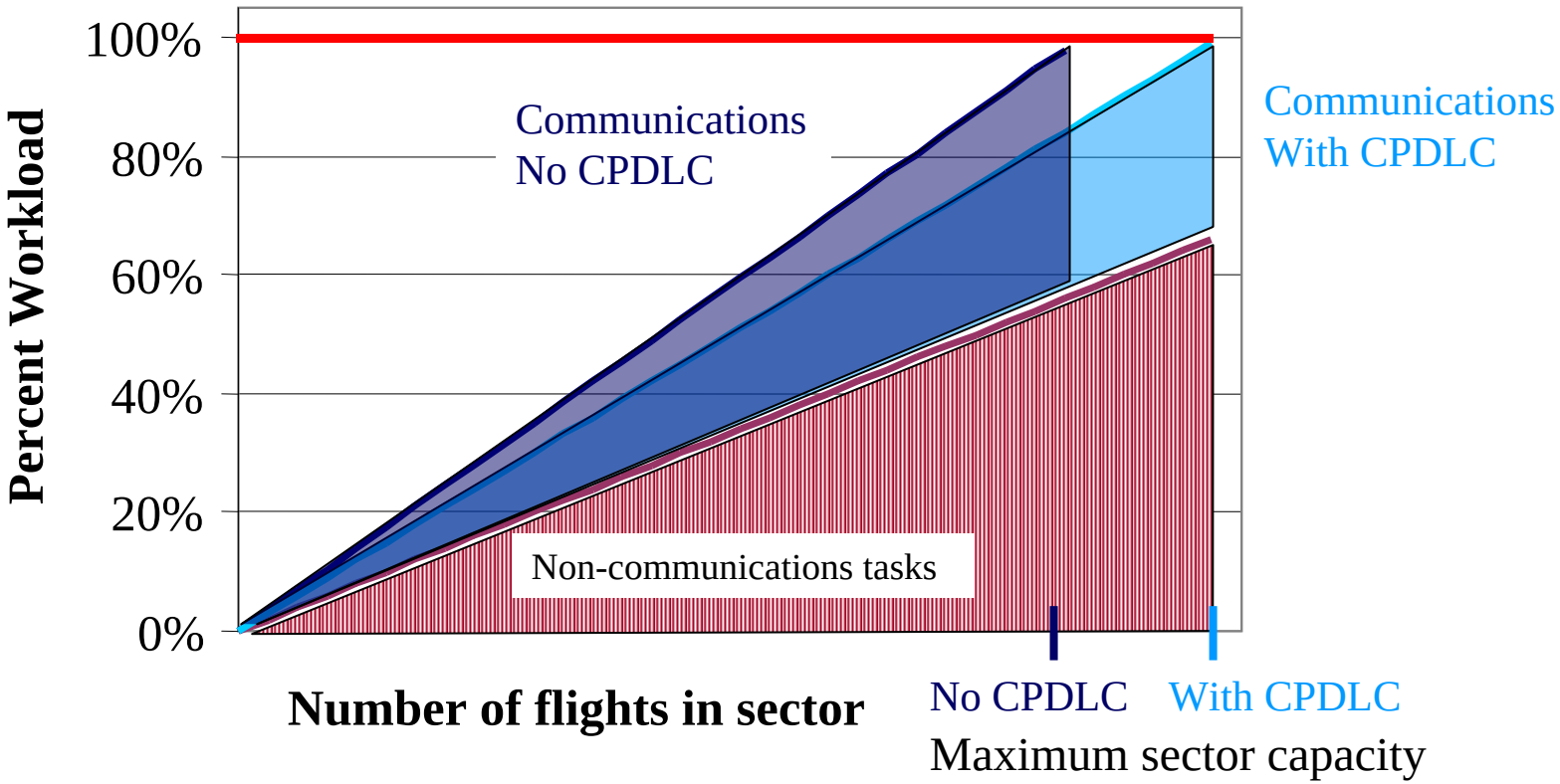
Voice Channel Utilization with CPDLC

- **CPDLC**
  - **Enhances En Route Controller productivity by automating communication which increases sector capacity**
  - **Reduced workload improves controllers' efficiency in vectoring for traffic**





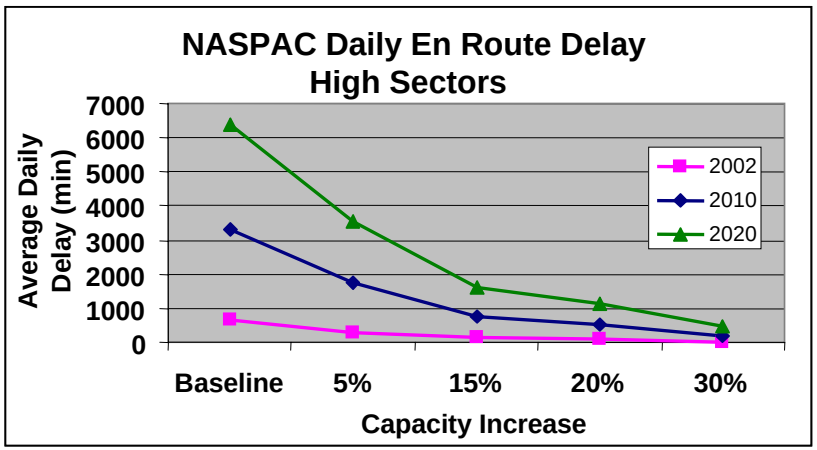
Model for Sector Capacity Increase

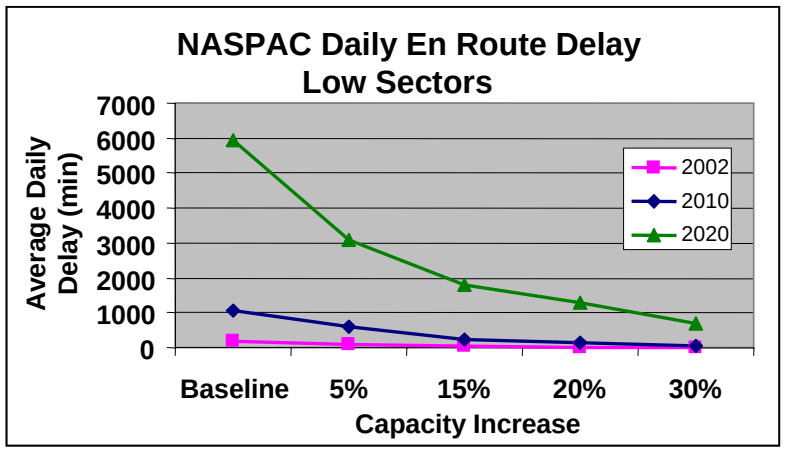


Modeled Delay from NASPAC

- **Advantages of NASPAC/DPAT Model**
  - **Captures sector capacity constraints**
  - **Allows full NAS Modeling**
  - **Supports Growth in Demand**

Good Weather Using Southern Region Routing





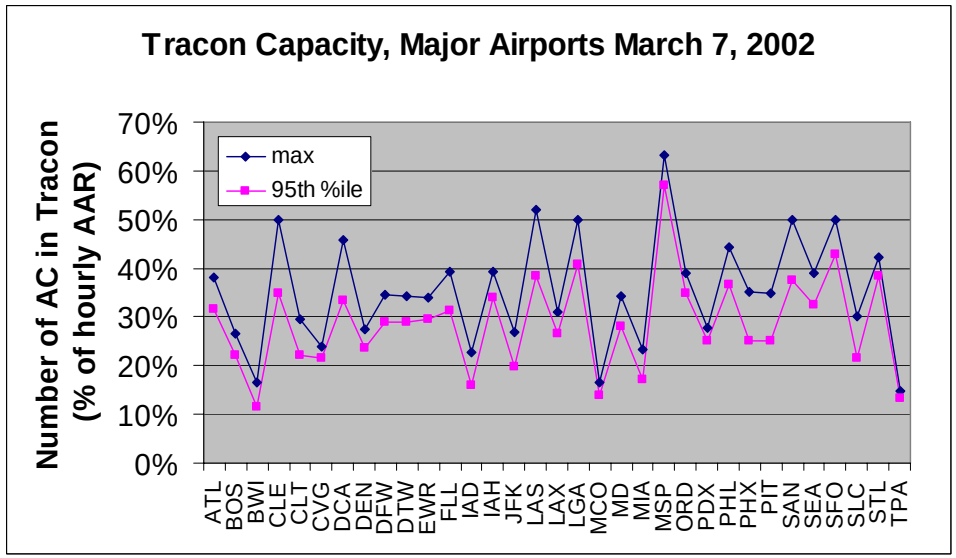
Modeling Problems Encountered

- **Issues Within NASPAC/DPAT**
  - **TRACON Capacity**
  - **Severe Weather**
- **Issues with Input Assumptions**
  - **Routing Assumptions Sensitivity**
- **Issues not Addressed by NASPAC/DPAT**
  - **Efficiency when Demand less than Capacity**

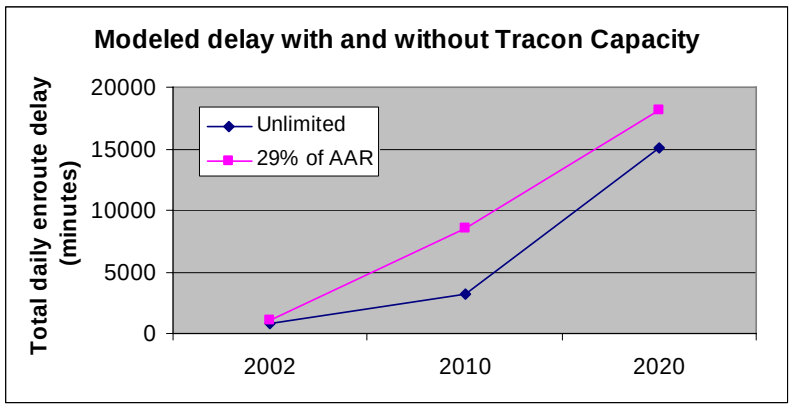
Problems encountered: TRACON Capacity

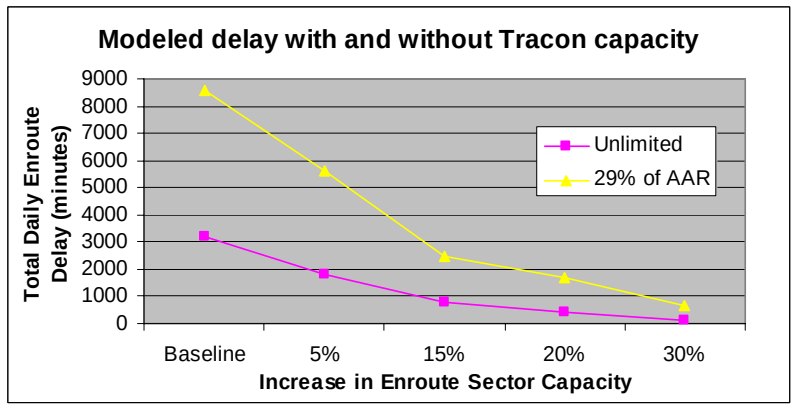
- In reality, airport congestion affects en route airspace
- Assigning finite capacity to TRACON airspace in model allows this “backup” to be simulated
- Tricky to get right
  - No well-defined standard for what that capacity should be
  - Most modelers decouple airport constraints from enroute constraints

Implementing TRACON capacity



Average of 95th percentile: 29%

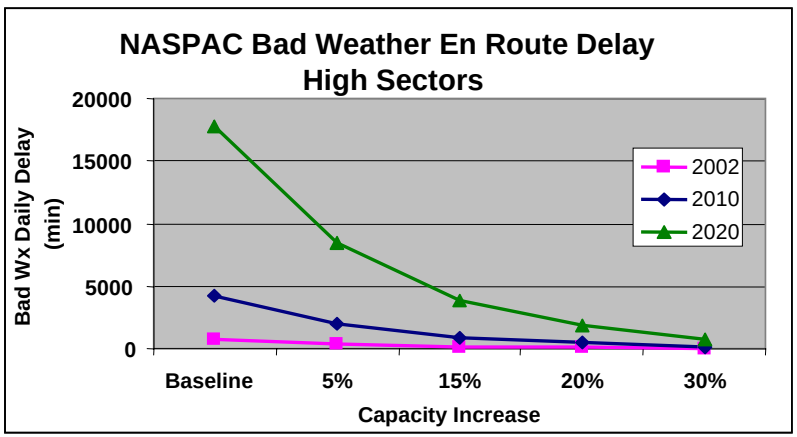


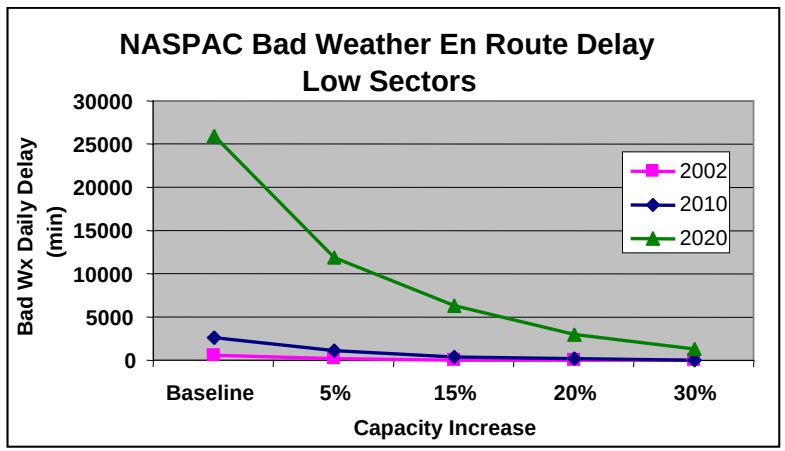


Severe Weather Modeling

- **Routing around severe weather increases number of areas where demand exceeds capacity**
- **Available models did not allow for routing around affected areas**
- **We used actual tracks as input trajectories**
  - **Weather has already been routed around, which may not have been necessary if more capacity had been available**

Bad Weather based on tracks "as flown"





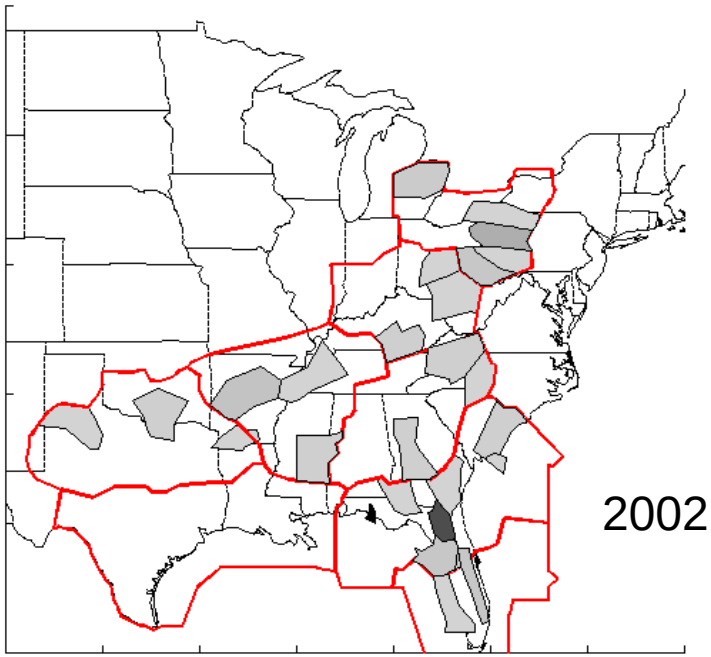
Sensitivity to Routing Assumptions

- **This is not necessarily a *modeling* issue per se**
  - **Underlines necessity for standardized scenarios**
- **Observed delay for given capacity in future scenarios is *very* sensitive to**
  - **Routing assumed**
    - **Great circles, pref routes, RNAV routes**
  - **Details of future scheduling**
    - **Forecast (TAF) gives ops counts, but not city-pairs**
    - **What about rolling hubs? More point-to-point?**

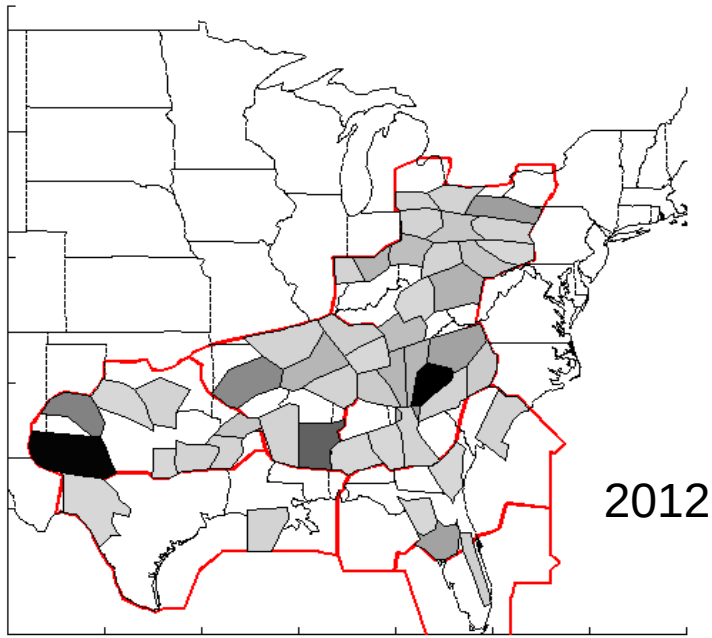
Modeled Daily Delay Savings in 8 CPDLC ARTCCs (minutes per day)														
	Year													
Routing Scenario	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Southern Region routing	0	0	212	445	639	831	987	1333	1679	2042	2418	2852	3462	3901
All Great Circle routes	0	0	2546	6697	10254	14678	18291	27840	37307	46835	56629	67232	79364	90873
Most likely value	0	0	424	891	1277	1661	1974	2665	3358	4084	4835	5704	6924	7803

Modeled Sector En Route Daily Delay

High Sectors



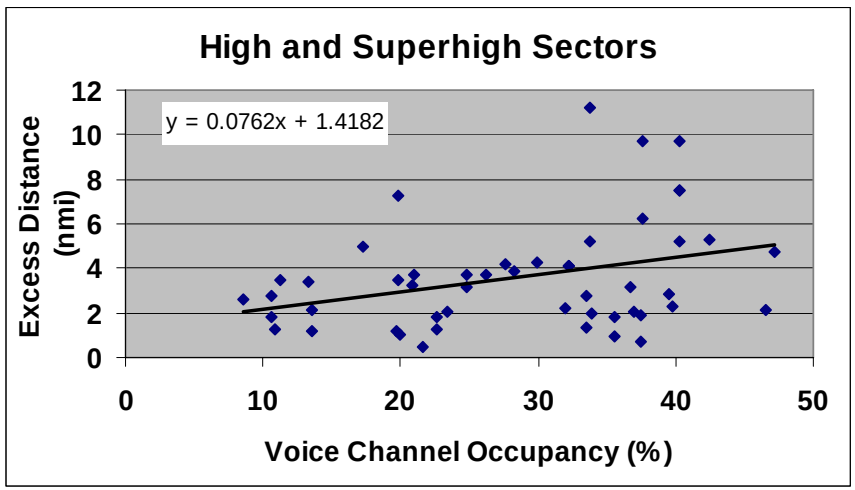
Many en route sectors are currently capacity constrained

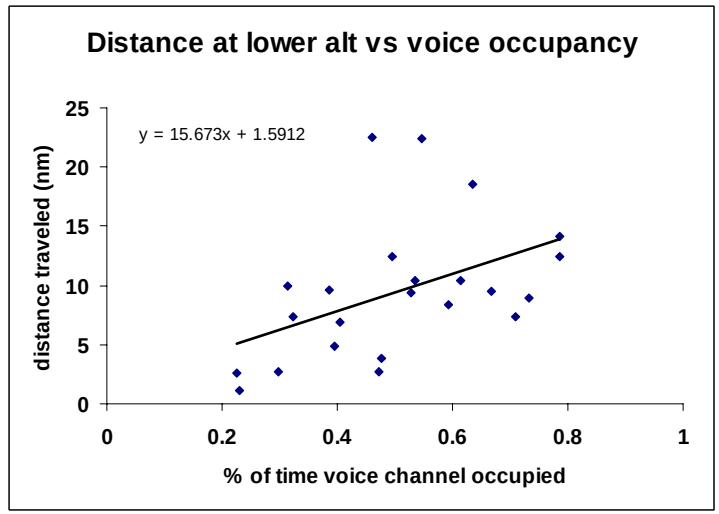


Capacity constraints in en route airspace will become more of a problem in the future

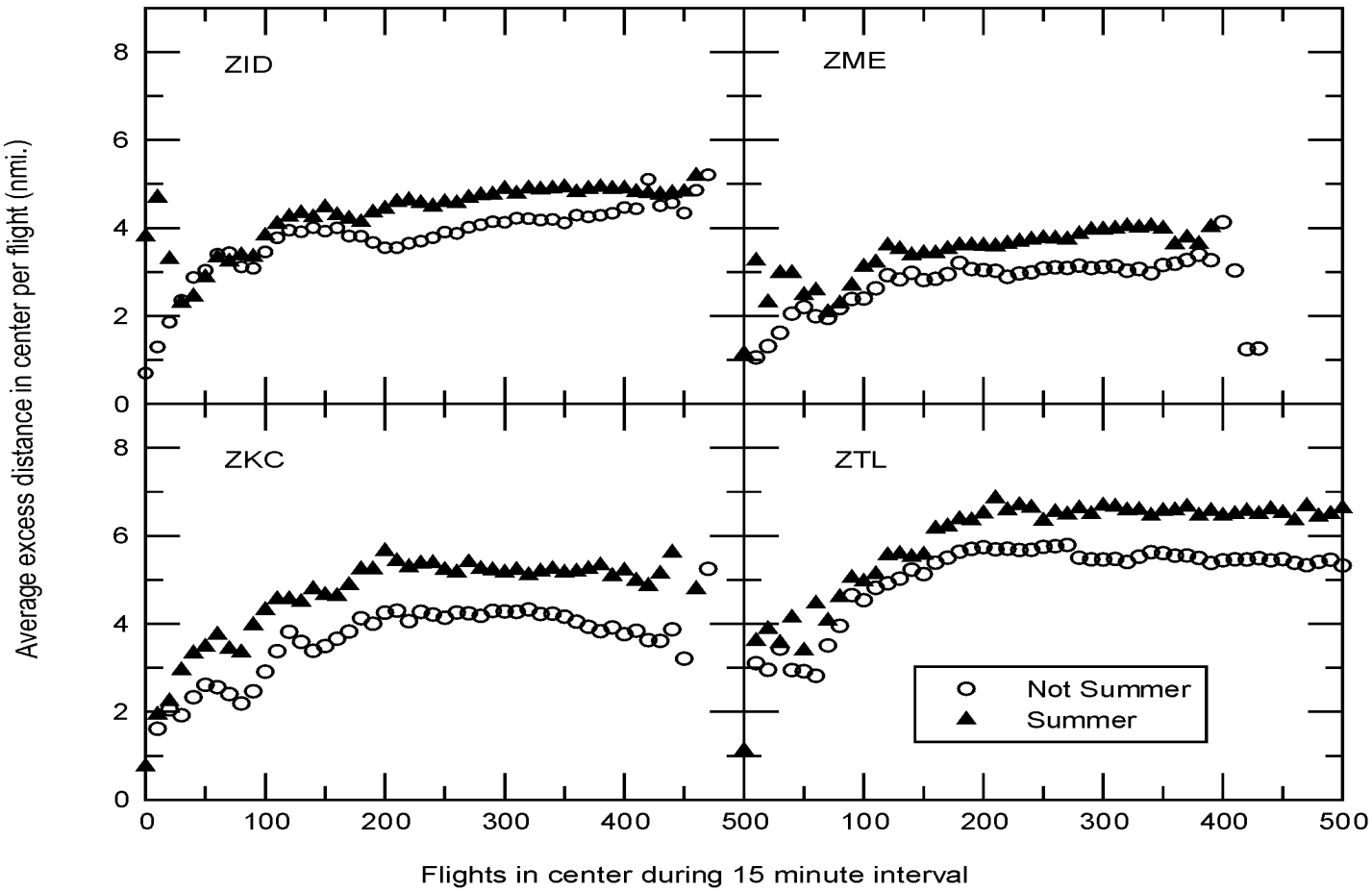
Trajectory Efficiency

- Queue-based enroute models apply no efficiency penalty when demand < capacity
- In practice, efficiency of conflict resolution and descent/ascent profiles vary with sector load
- CSSI (P. Lucic, S. Mondoloni, W. Weiss) constructed an ad hoc model built on TTT to estimate benefit





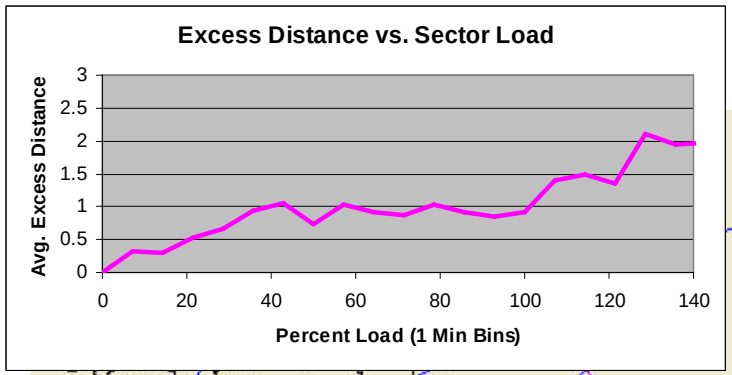
En Route Efficiency Pool – 'Excess' Distance



Efficiency measure

Here’s what we’d like to see a model do…

Modeling Airspace Performance



If sector load < capacity,

Adjust dwell time

Modeled aircraft approaches new sector

DFW

ATL

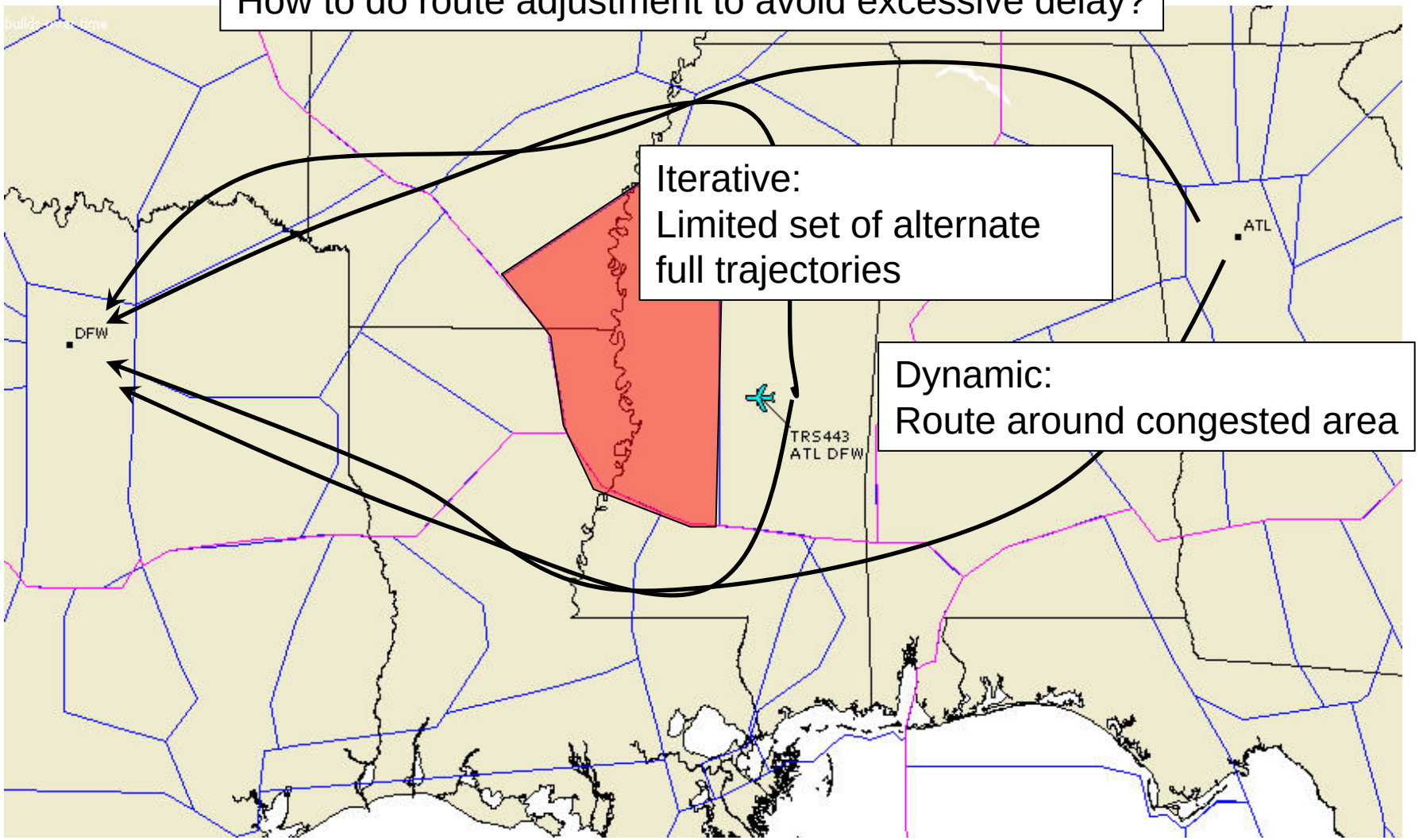
TRS443
ATL DFW

If sector load > capacity,

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

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

Modeling Airspace Performance

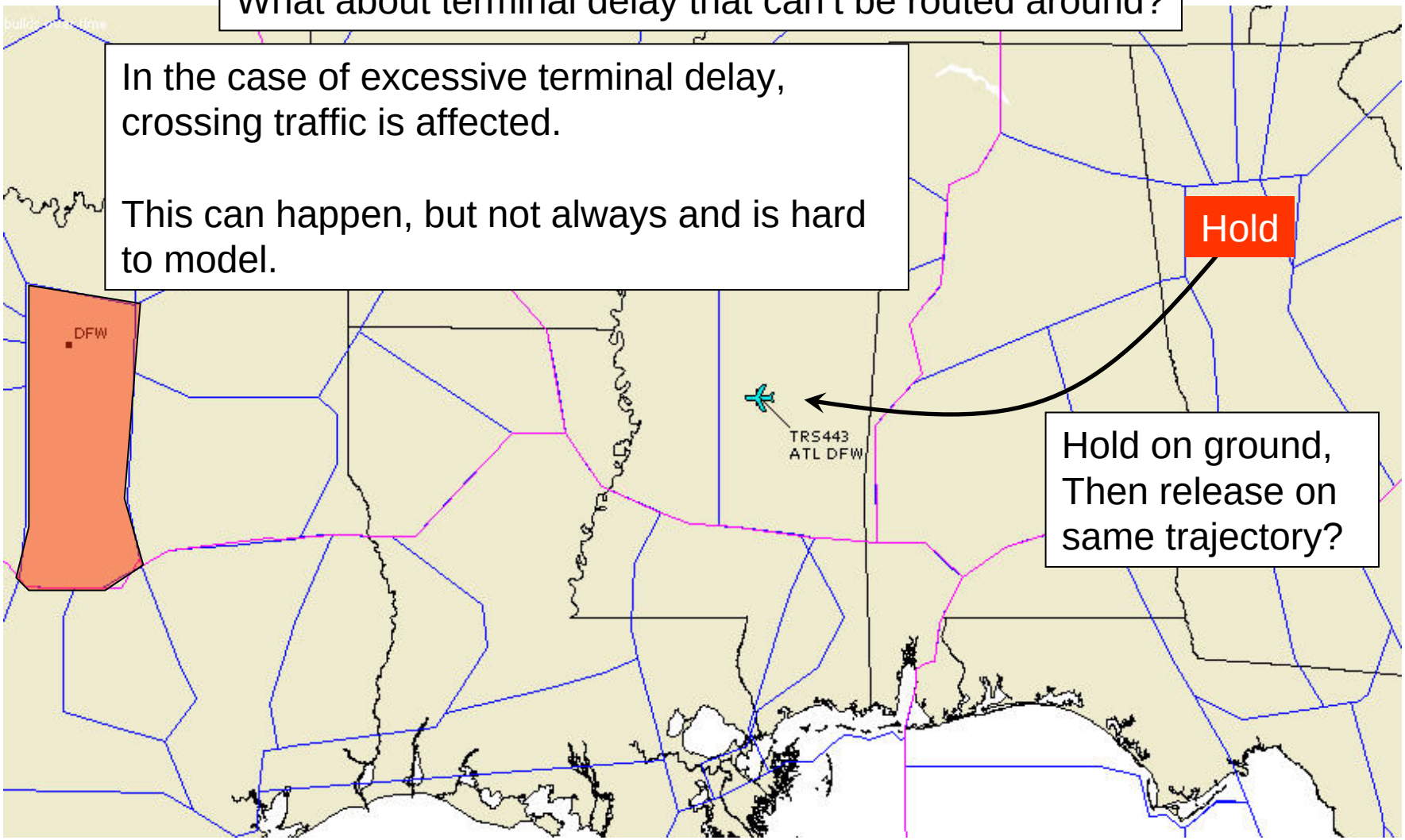


Modeling Airspace Performance

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

In the case of excessive terminal delay, crossing traffic is affected.

This can happen, but not always and is hard to model.



Backup Slides

What is CPDLC?

- **CPDLC allows digital text messaging between enroute controllers and pilots**
  - **Replace the voice messages:**
    - **Initial Communications**
    - **Transfer of Communications**
    - **Altimeter Setting**
  - **Also transmits locally-defined menu of common messages**
- **Benefits Include:**
  - **Reduced voice channel occupancy**
    - **Greater communications availability → More efficient maneuvers**
    - **Decreased controller workload → Increased sector capacity**
  - **Increased communications accuracy**
    - **Reduced readback errors**
    - **Reduced OD/OE**

Model Needs 1: Input

- **A model should compute trajectories of aircraft from input files:**
  - **Parse flight plans to produce route of flight**
  - **Include wind effects in modeled trajectory**
  - **Use individual airplane characteristics to model aircraft performance**
  - **Compute pierce and dwell times for all airspace elements for each aircraft**
  - **Allow linkage of different flight legs**

Model Needs 2: Airspace

- **A model should simulate the behavior of the full airspace:**
  - **Include enroute centers, terminal areas and runways**
  - **Include capacity limits on airspace elements, specifically sector and TRACON flight count limits and runway operation rates for airports**
  - **Include demand-dependent airspace performance based on real-world data (i.e. increase in excess distance in enroute sectors when busy, change in runway service times at different demand levels)**

Model Needs 3: Dynamic Adjustments

- **A model should allow dynamic adjustments to aircraft trajectories based on the current state of the airspace:**
  - **Include the ability to reroute aircraft at different levels of control**
    - **Automatic rerouting around congested sectors, to emulate behavior of controllers and traffic management units**
    - **Strategic rerouting as part of traffic flow management initiatives**
  - **Include ability to implement traffic flow management initiatives, such as ground delay programs**
  - **External perturbations to the airspace, such as convective weather or security issues, must the handled by the model**

Model Needs 4: Output

- **A model should generate detailed reports, both summary (full-run) and at selected sampled times:**
  - **Sector and TRACON loads**
  - **Aircraft trajectories**
  - **Aircraft delay**