Progress in Identifying and Safely Utilizing the Available Capacity During Severe Convective Weather in Congested Airspace

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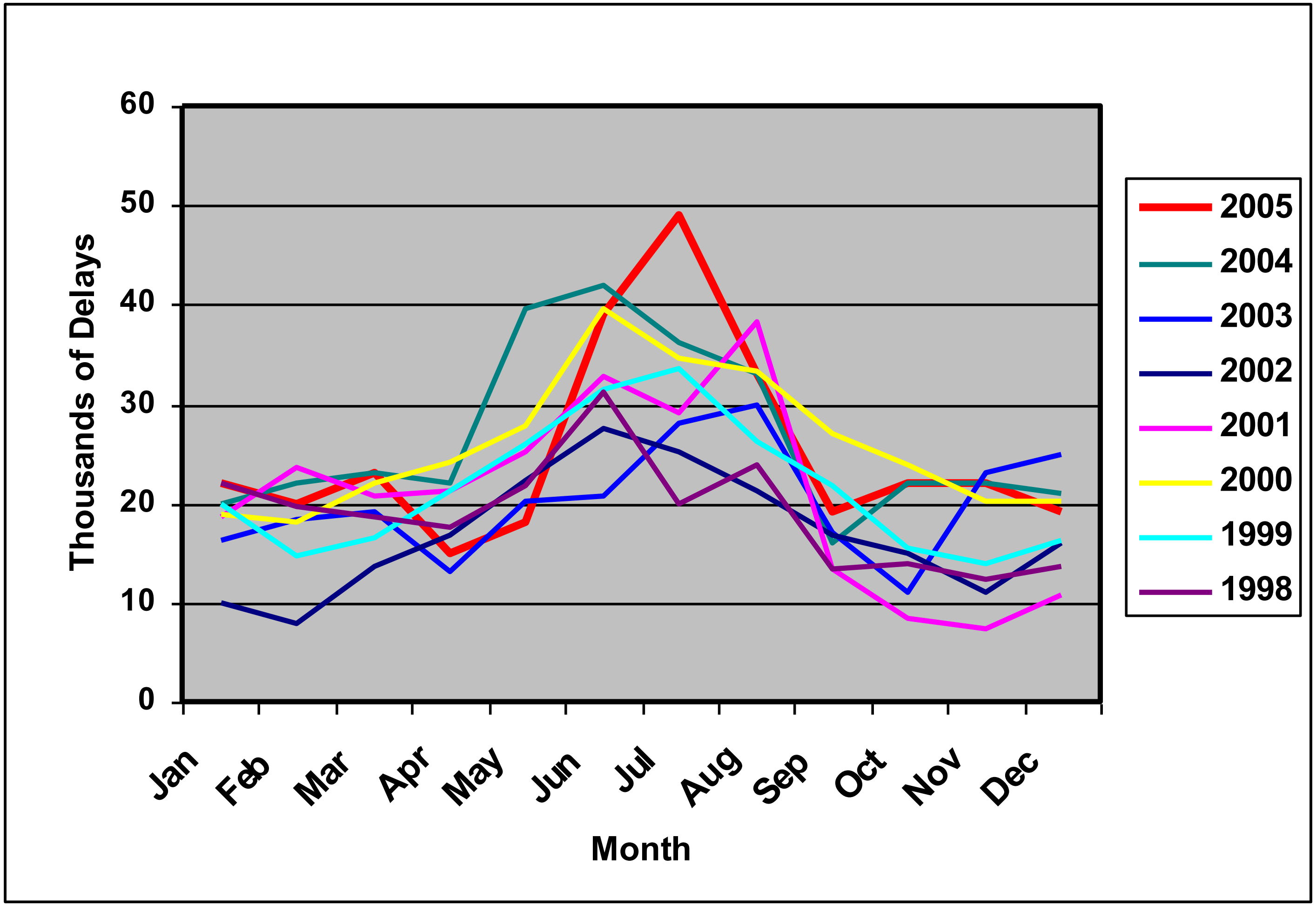
Outline

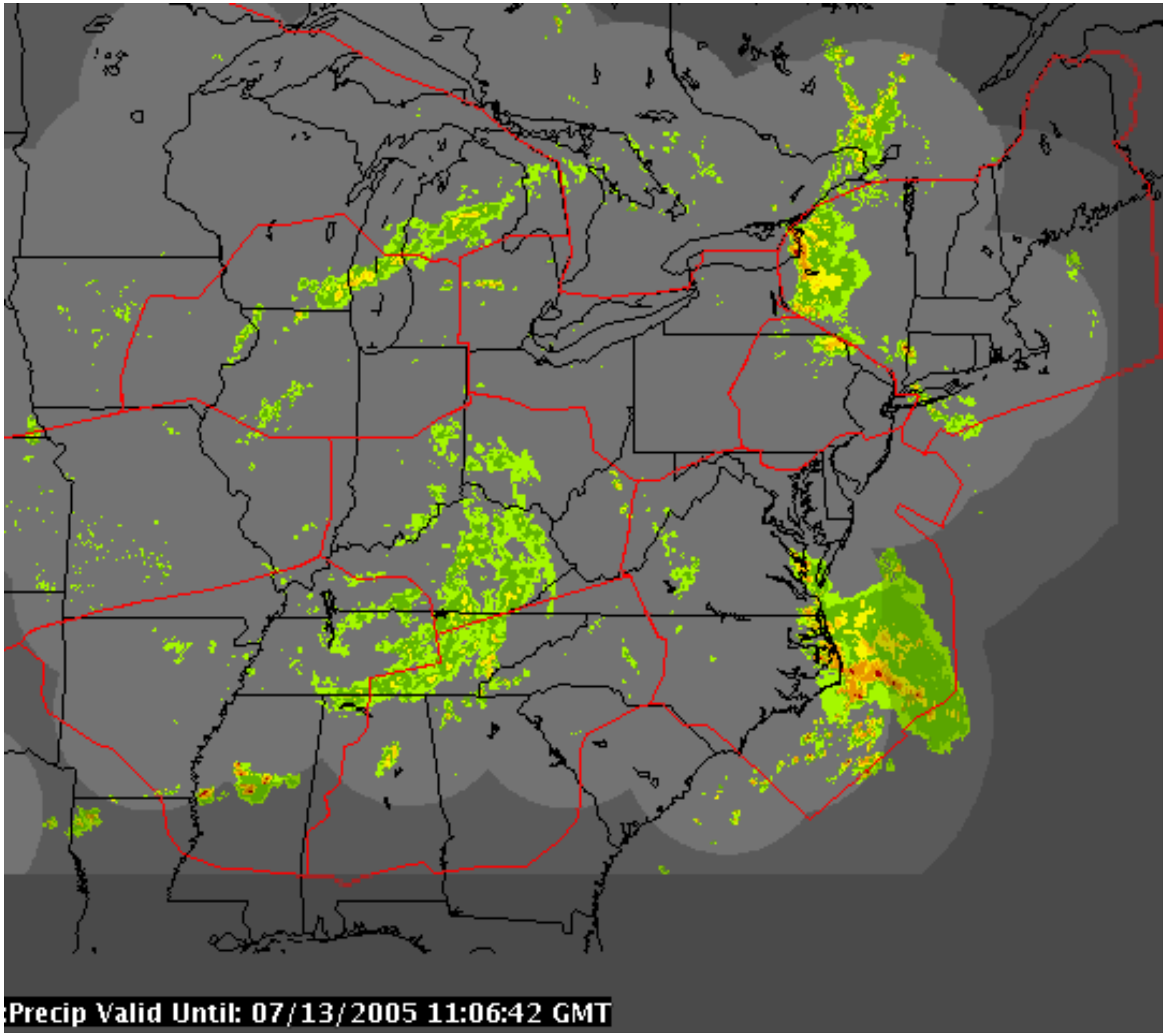
- Challenges
  - Difficulties in demonstrating aviation weather decision support benefits
  - The national air system (NAS) as a congested network operating in a nonlinear regime
- Determining and utilizing the available capacity
  - Capacity estimation from forecasts
    - Understanding pilot behavior
    - Combining weather forecasts, pilot models and ATC structure
  - The human side: who are the key decision makers and how important is it to provide them with information
- Summary

NAS OPSNET Weather Delays



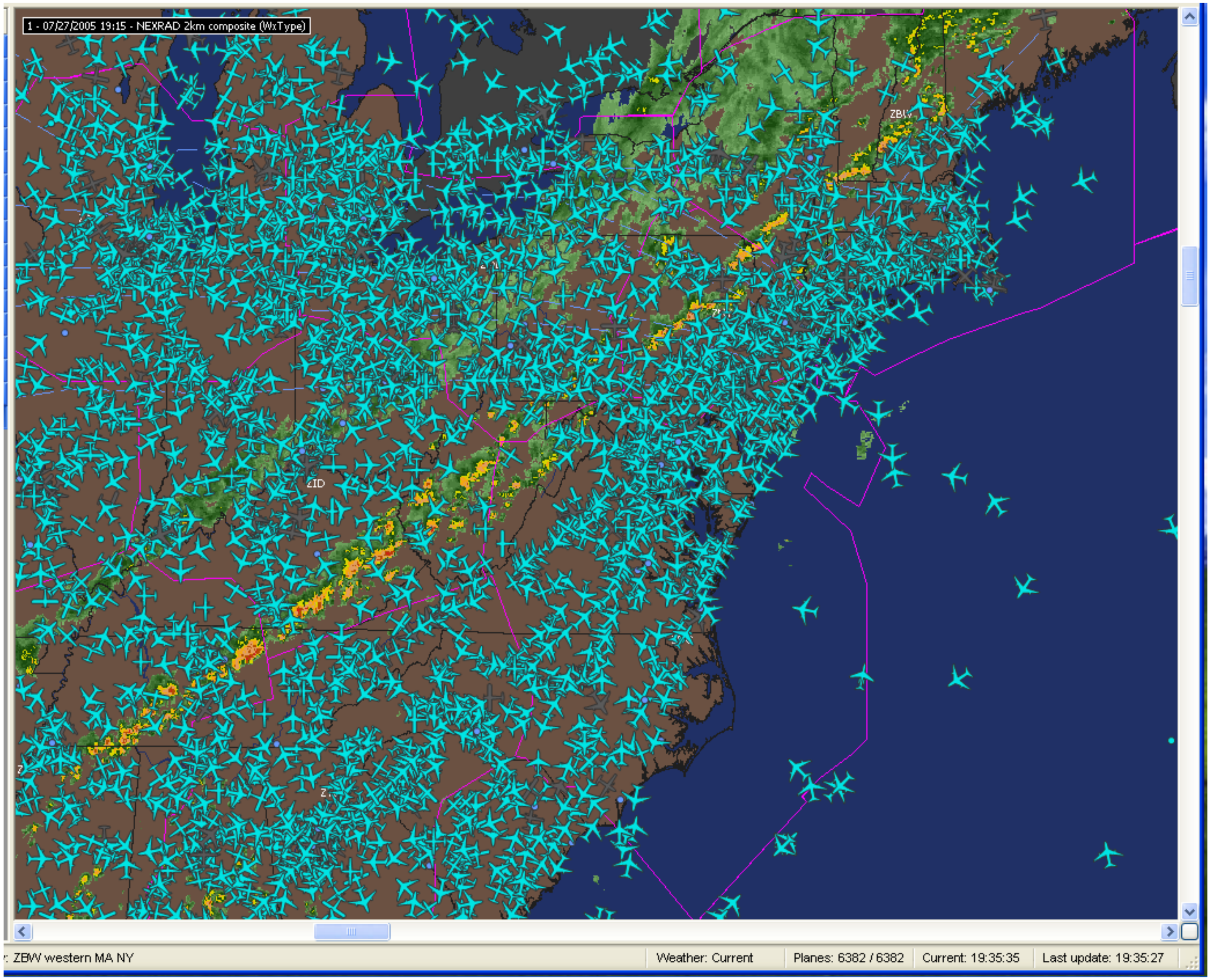
Delays have continued to grow despite deployment of CCFP, NCWF, ITWS, CIWS and many ATM/TFM systems …. users are getting unhappy

13 July 2005 – A "Worse Delays" Day



OPSNET
3,662 delays
3,718 hrs

Aircraft Plus Wx -- 27July 2005, 1915Z



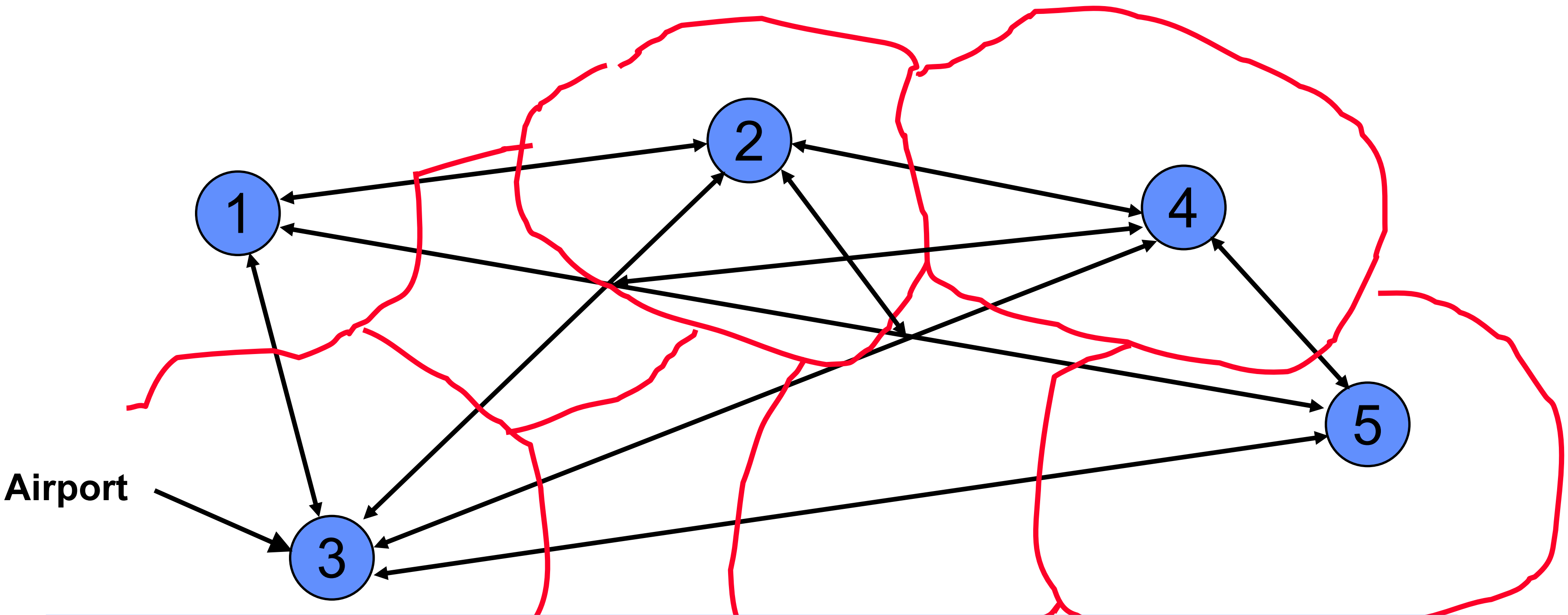
OPSNET
2,387 delays
2,420 hrs

What is Generating the US Delays: NAS Network Constraints

<u>Paradigm A</u>: Insufficient adverse weather capacity at airports

<u>Paradigm B</u>: Convective storms impact the network by reducing the capacity of jet routes, en route sectors and terminals.

Bad delay days invariably involve en route <u>and</u> terminal demand > effective capacity… ability to <u>reroute</u> is a key factor in delay magnitude



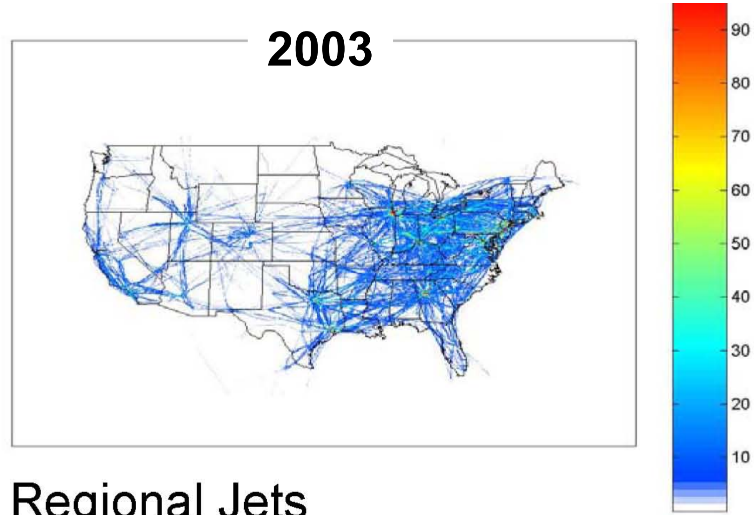
Ground delays due to GDPs (or, AFPs) correspond to nonlinear queue delays

Changing Fleet Mix Increases High Altitude Sector Congestion

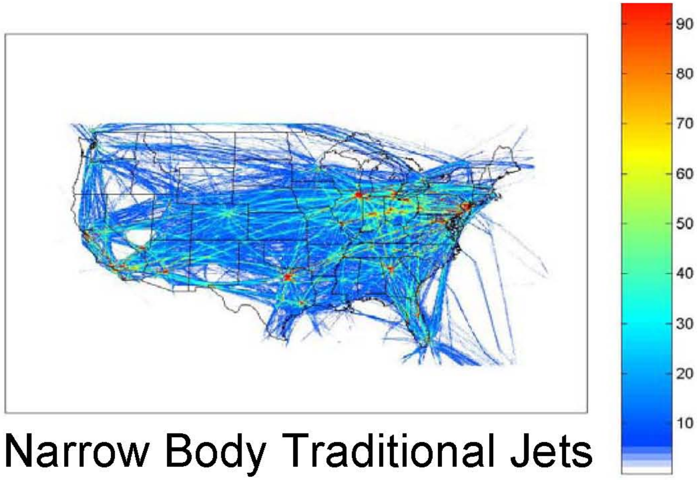
1998

Regional Jets

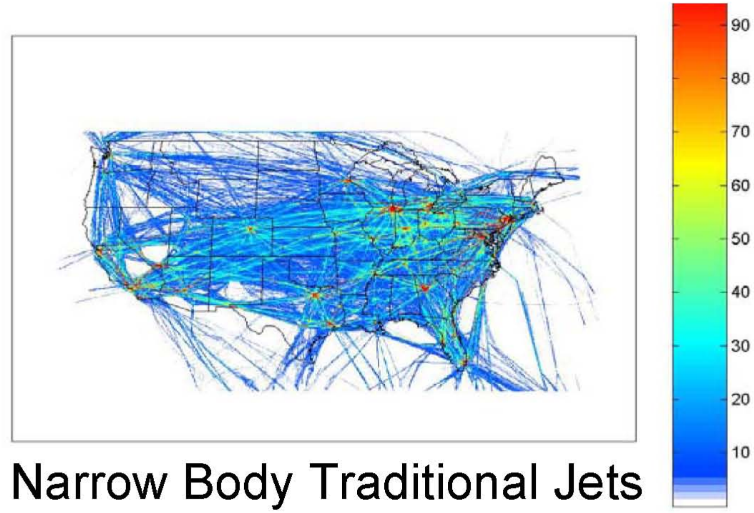
2003



Regional Jets



Narrow Body Traditional Jets

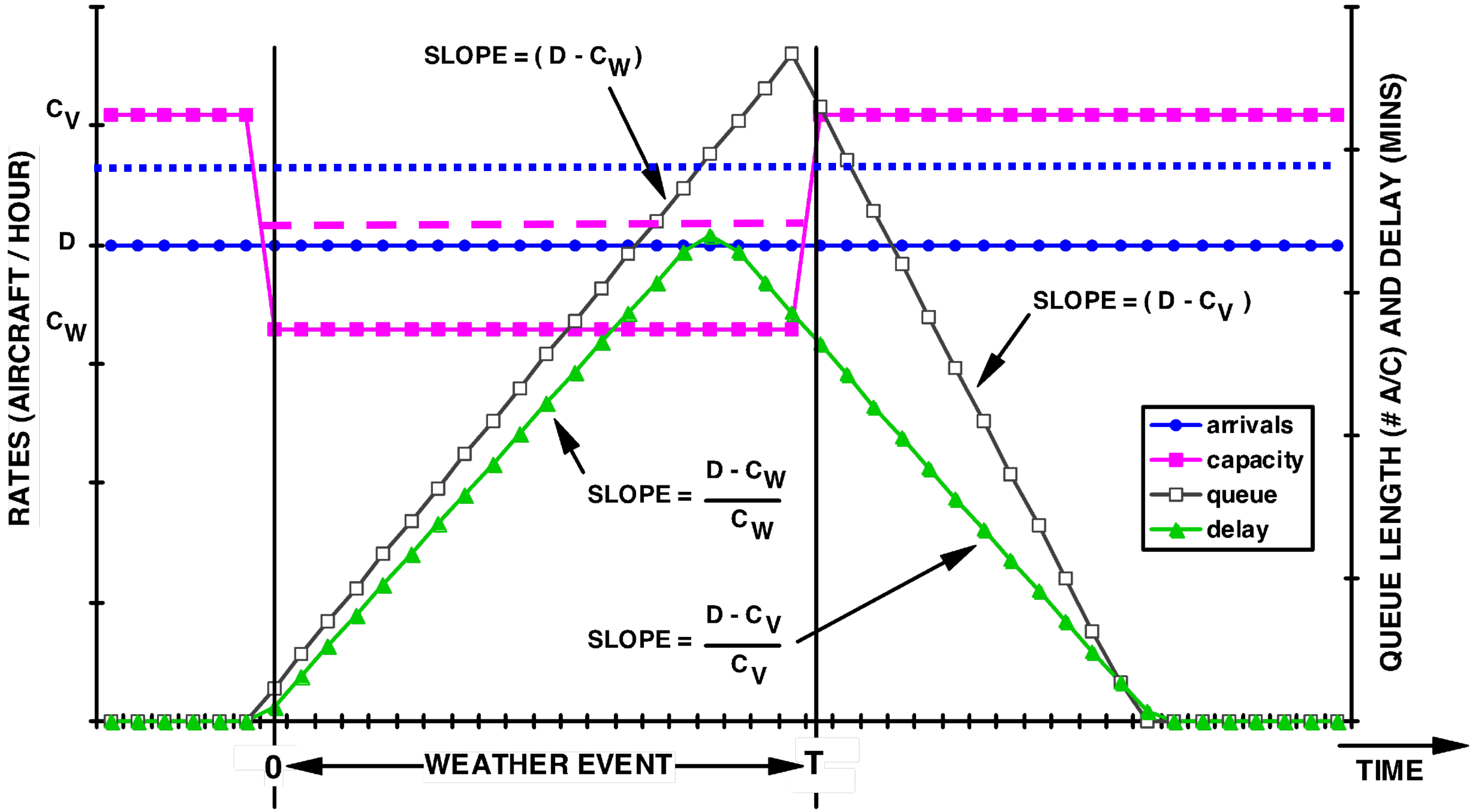


Narrow Body Traditional Jets

Mozdzanowska, A. and R. J. Hansman (2004)

Queue Delays

Queue manifestation: Holding patterns, Ground delay programs (GDPs), Ground stops

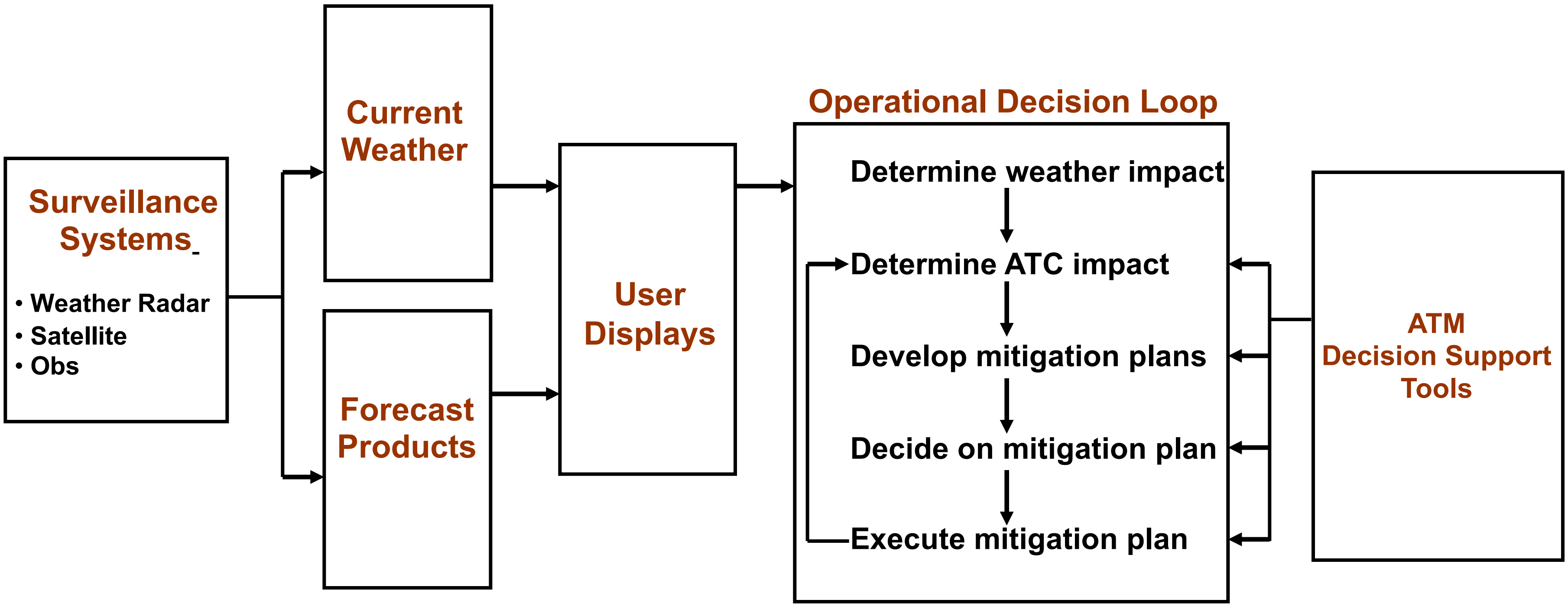


Σ delays = $0.5\ T^2\ (D - Cw)\ (Cv - Cw)/(Cv - D)$ {

<u>Very</u> nonlinear

<u>Square</u> of duration

Weather Impact Mitigation Paradigm



Benefits are achieved only when the operational decision loop is executed in a timely manner

Forecasting the capacity impact of convective weather is a key element of the decision loop

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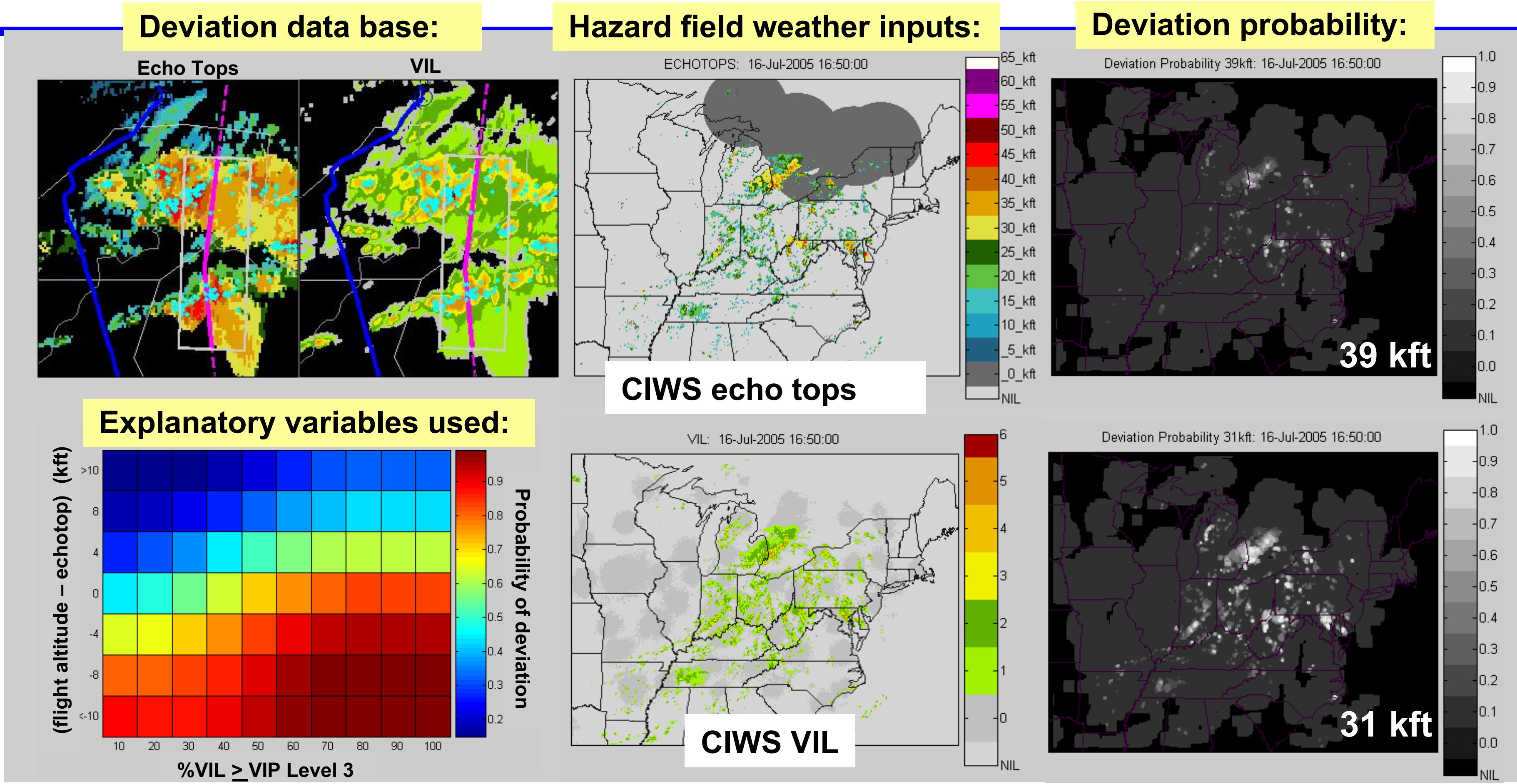
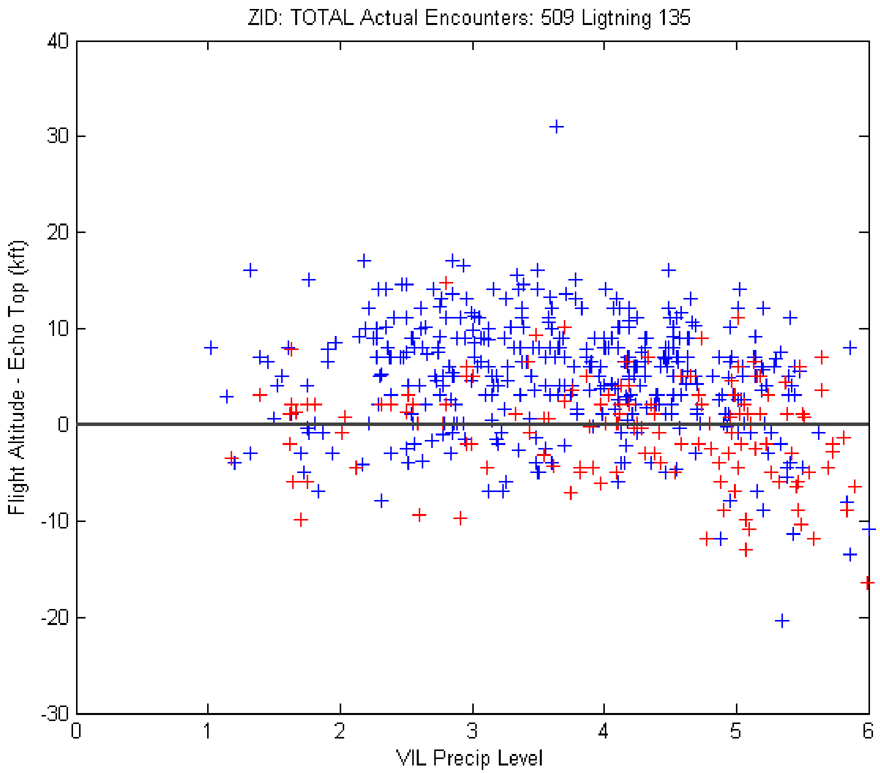
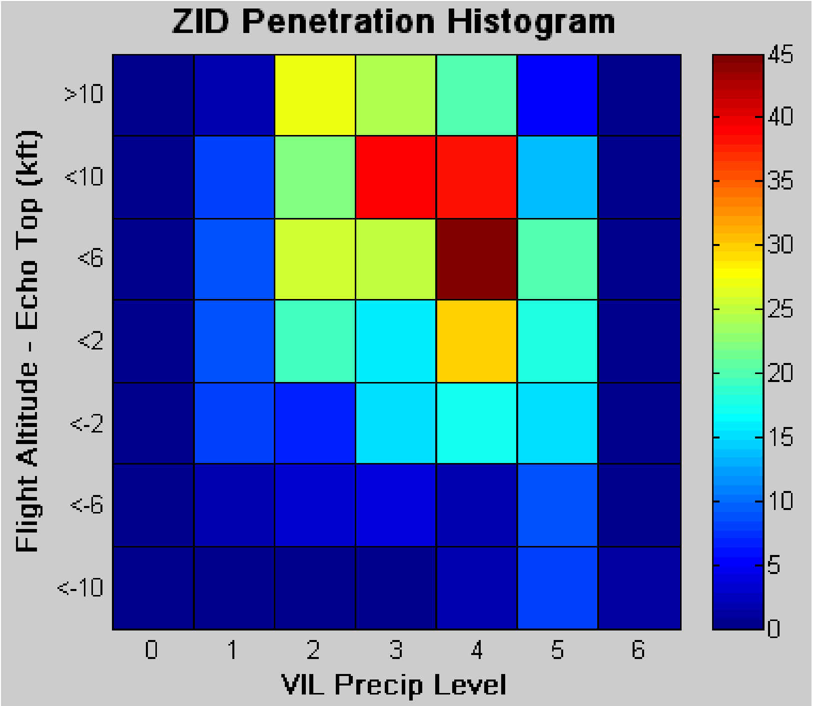
Convective Storm Flight Deviation Hazard Field Generation



- **NASA-sponsored Convective Storm Flight Deviation (CSFD) study produced initial models for pilot preference in convective weather**
- **CSFD models produce deterministic and probabilistic, 3D hazard fields**

ZID Storm Penetrations



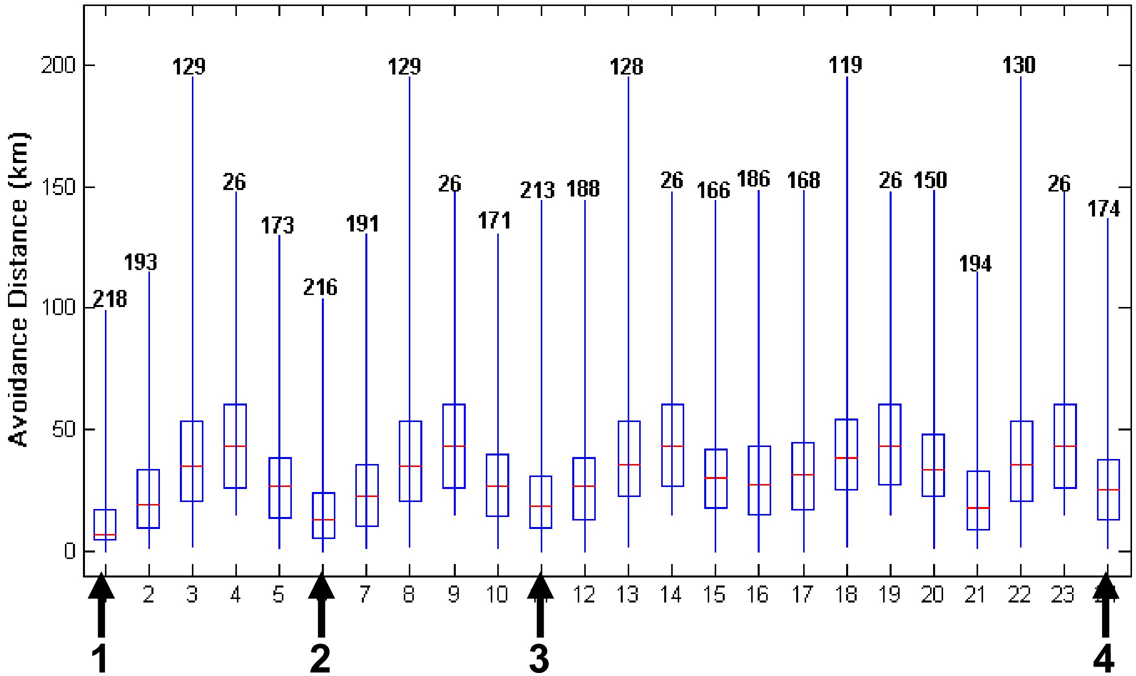


(Aircraft altitude – storm echo tops)vs. VIL level for all actual trajectory weather encounters.

Blue + indicate encounters where the neighborhood cloud to ground lightning count was <10; red + indicates counts >=10.

Data points above the 0-line represent over-flights, where flight altitude >echo top height.

Distance from Storm Features for Storm Deviations



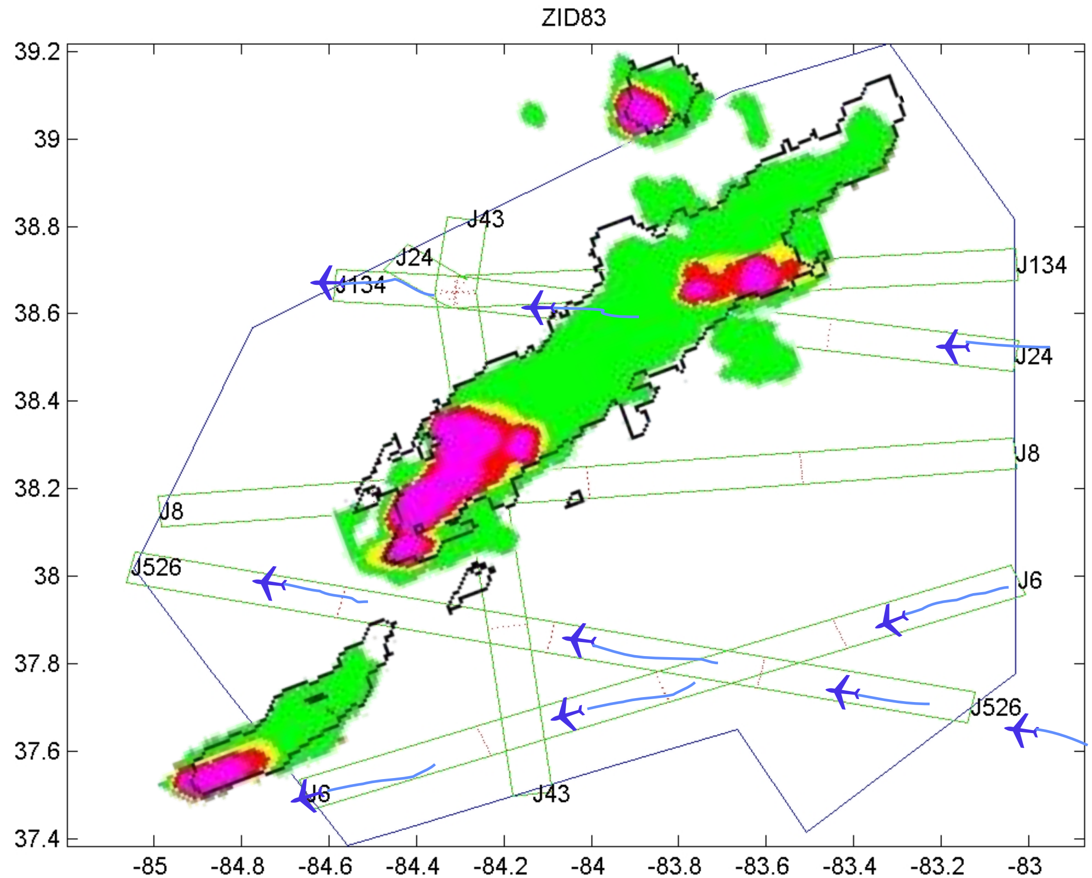
75% of deviations are within 25 km of VIL level 3 reflectivity and, within 33 km of VIL level 4

Minimum avoidance distance statistics. Box plots showing quartiles of avoidance distance for weather features. The number at the top of each box plot is the number of convective hazards that included the weather feature. Arrows indicate VIL level 2 (arrow 1), level 3 (2), level 4 (3) and echo top at flight altitude (4) boxes.

From NASA-sponsored Convective Storm Flight Deviation (CSFD) study

Modeling En Route Sector Capacity Reduction Using Route Blockage (RB)

- **Weather Hazard Fields (WHF) generated using weather radar based data (or, forecasts) and an empirically developed model for pilot route decision making**
- **Route blockage calculated by overlaying WHF on NAS route structure**



RB = 50%

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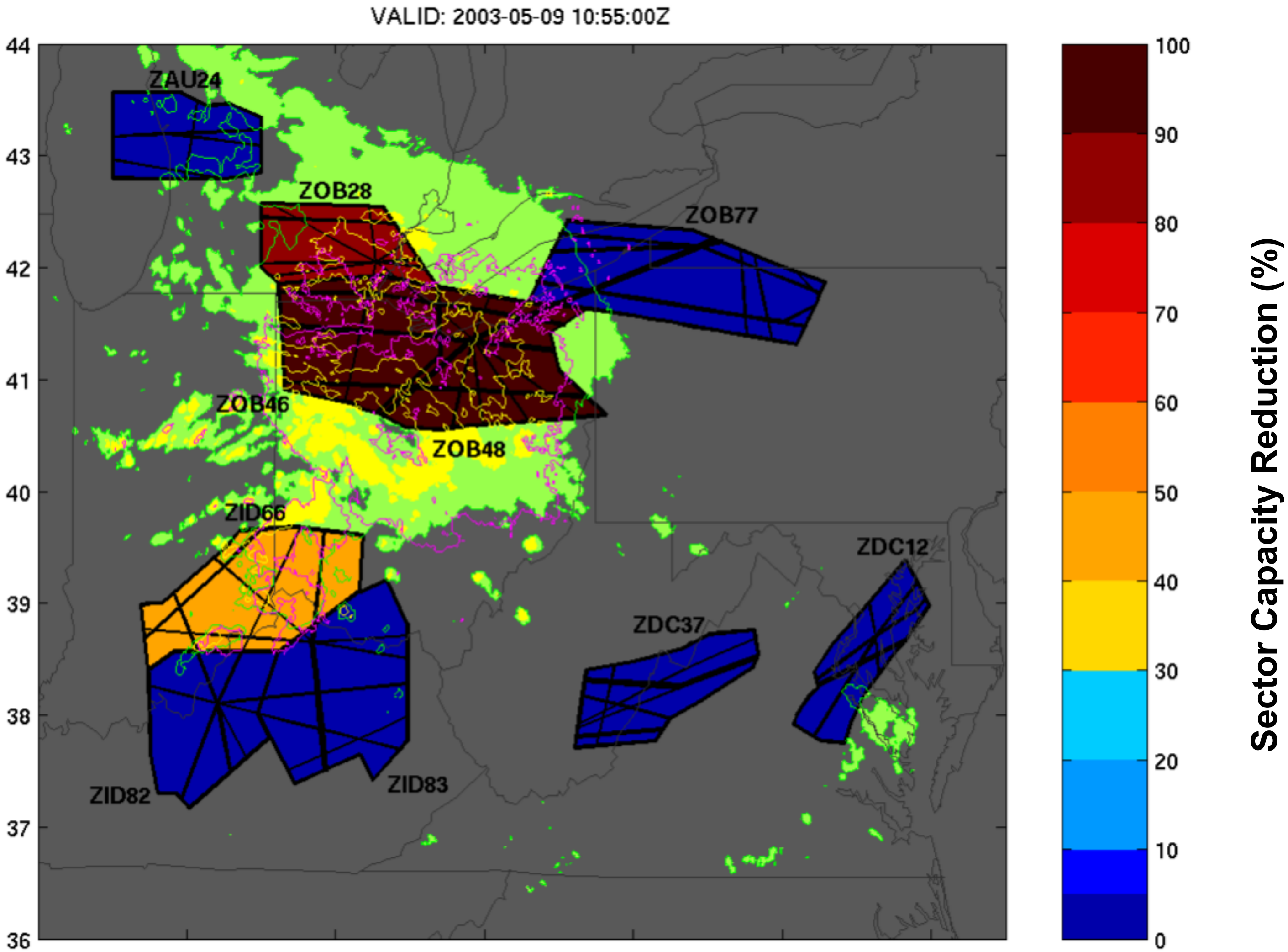
Available Sector Capacity: 9 May 2003



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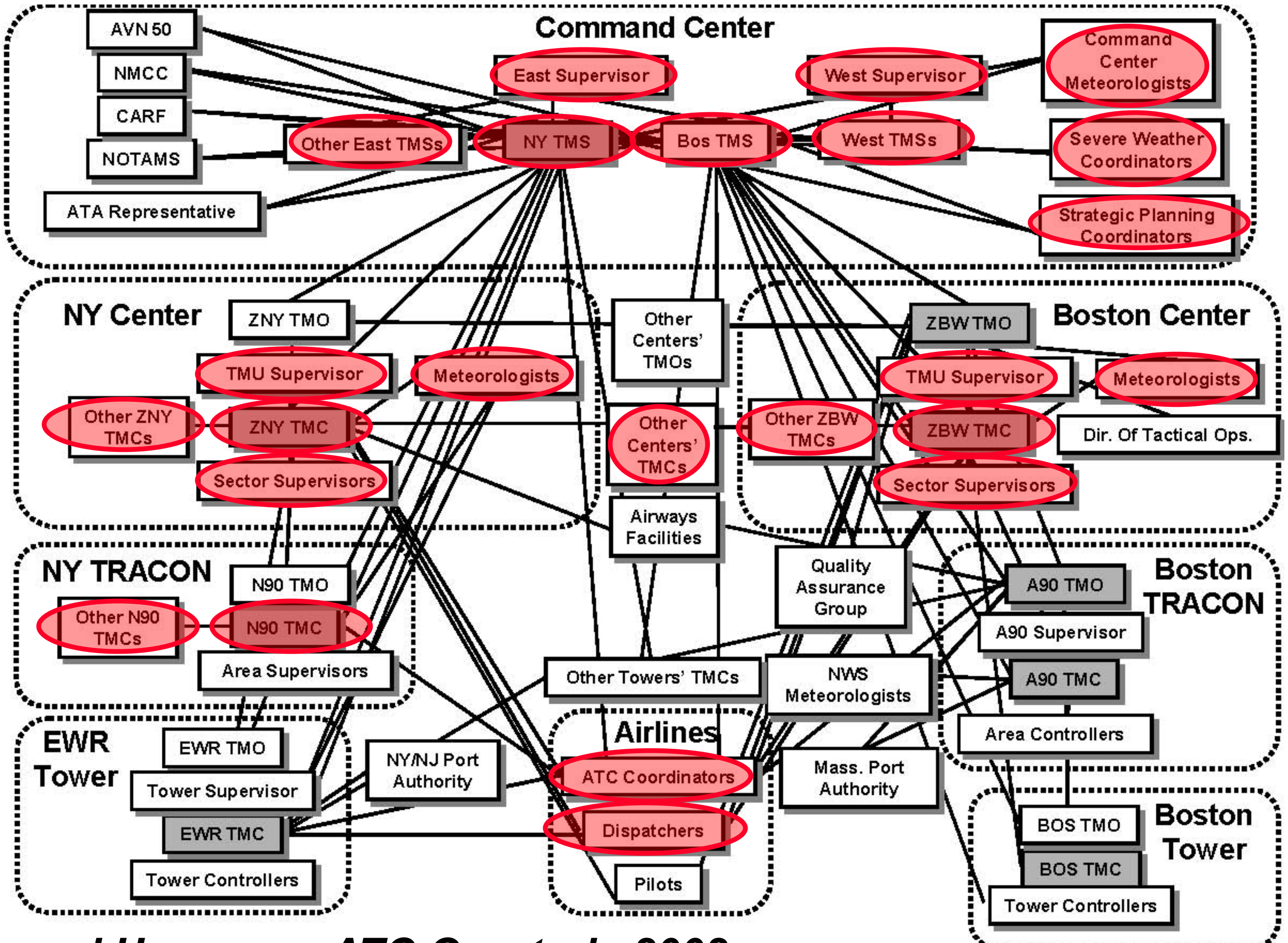
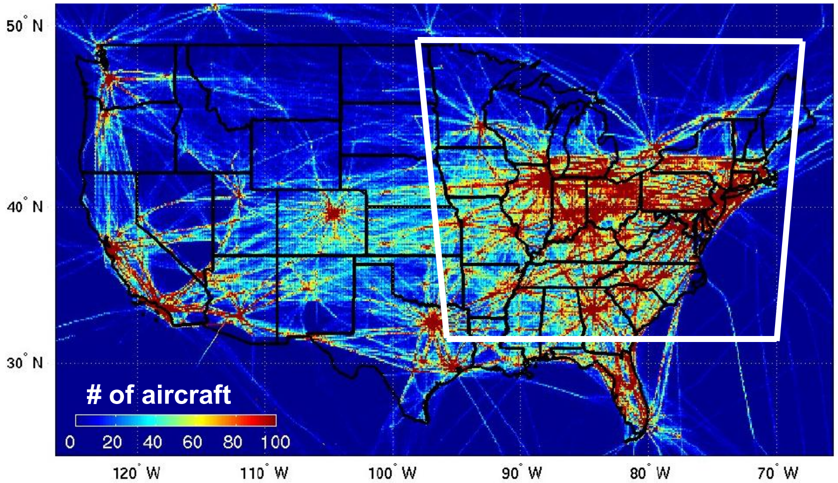
A Congested Network Necessitates Greater Coordination for Decisions

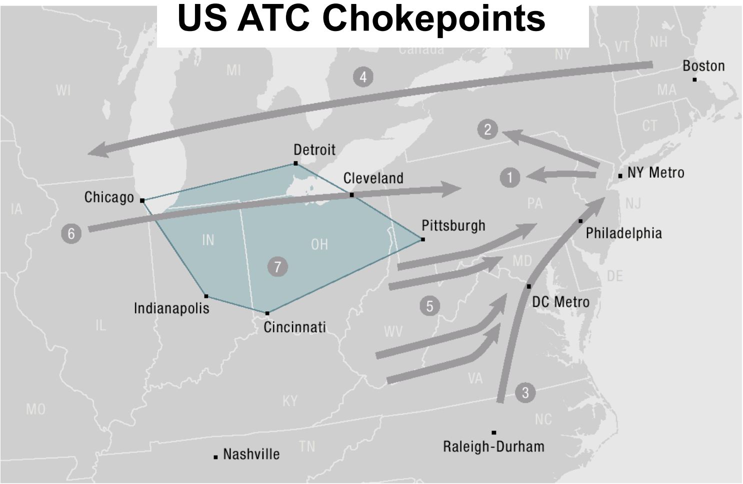


Davison and Hansman, ATC Quarterly 2002

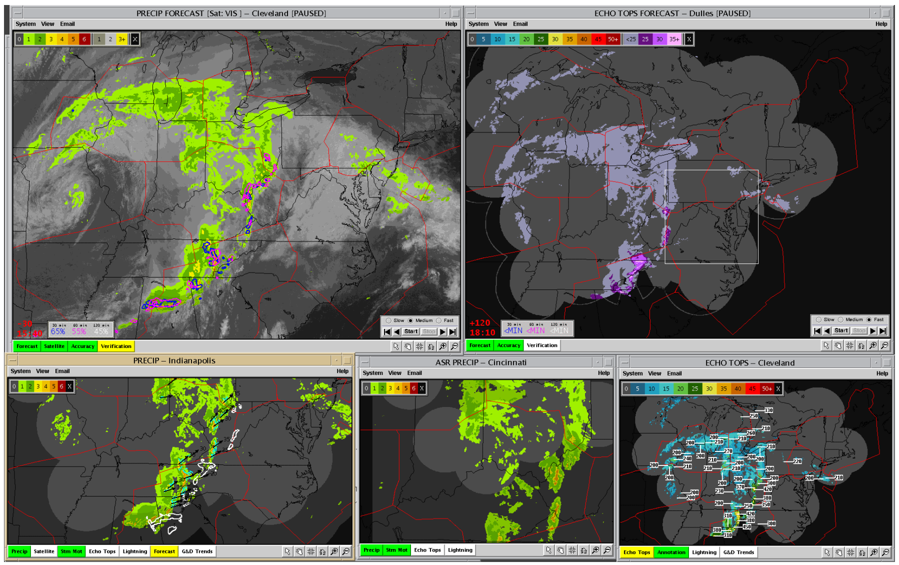
Corridor Integrated Weather System (CIWS)

Air Traffic 09/12/02 1000 UTC – 09/13/02 1000 UTC





From FAA 2001 ACE Plan



System Features

- 0-2 hour forecasts of both precipitation and echo tops
- Providing displays and operationally oriented training to key decision makers
- Real time forecast scoring
- ATM – Wx integration [Route Availability Planning Tool (RAPT)]
- Operational benefits assessments

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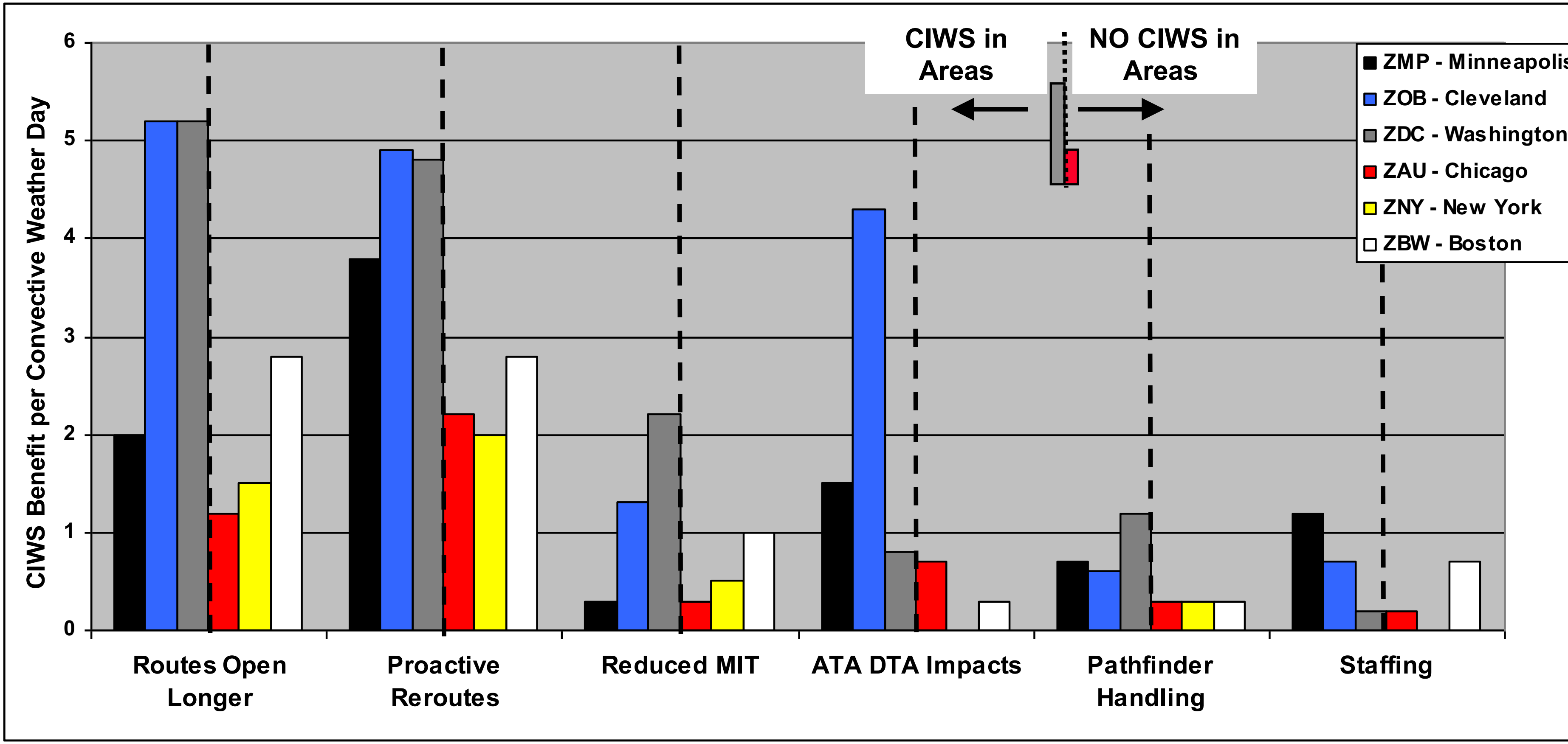
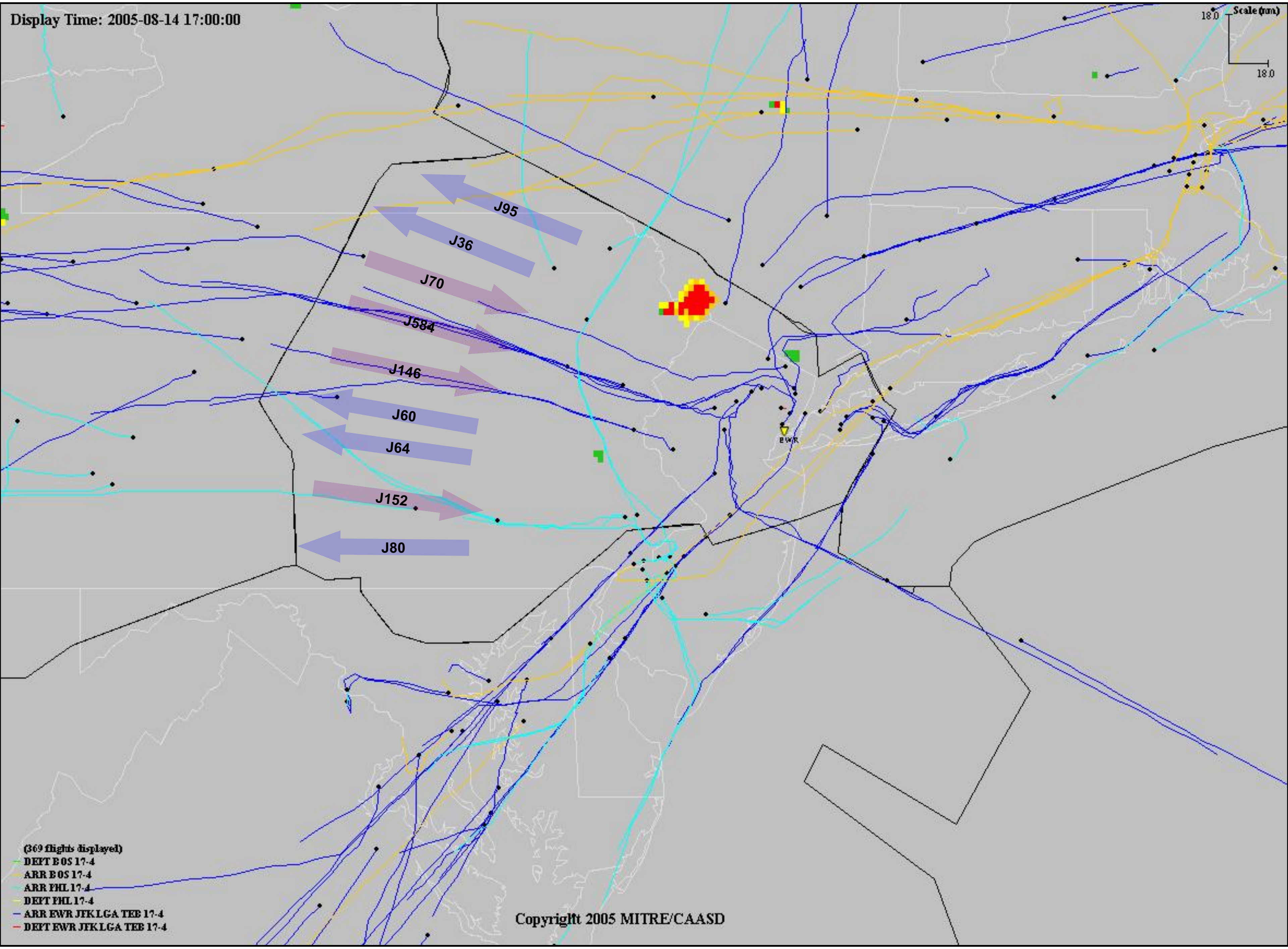
CIWS 2005 Benefits Comparisons
ARTCCs With and Without CIWS Displays in Areas



ZMP was a new user of the CIWS system; ZBW was very experienced

Summary

- The national air system (NAS) is an increasingly congested network, operating in a nonlinear, queue-dominated mode when adverse convective weather occurs
- Capacity estimation for convective weather is essential for both real time decision support tools (e.g., AFP) and, NAS performance analyses
- Active research underway to develop and validate
  - Pilot performance derived convective storm avoidance models
  - Capacity impact based on route blockage
- Consideration of <u>both</u> storm vertical structure <u>and</u> storm reflectivity is essential for en route capacity assessment
- Understanding the decision process so as to provide essential information to all the key users is a critical element of utilizing the available capacity.



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J584
J146
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J152
J80
EWR
(369 flights displayed)
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ARR BOS 17-4
ARR PHL 17-4
DEPT PHL 17-4
ARR EWR JFK LGA TEB 17-4
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