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Estimating Avoidable Delay in the NAS

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Outline

- Motivation
- The Bertsimas-Stock model for TFMP.
- A case study: Aug 24, 2002.
- Benefits assessment of CIWS echo tops product.
- Conclusions and contributions.

Motivation

- Given schedule, optimize airspace (sector, airport) usage through effective holding/routing strategies (Bertsimas et. al., 1995) in response to time-varying capacity.
- Could be viewed as a
  - Decision support tool.
  - Performance evaluation/ benchmarking tool.
  - Benefits assessment tool.
  - Network design system.
  - Pricing support mechanism.

Model Description (Data)

- Schedule (OAG) and filed flight plan.
- Time each aircraft spends in a sector (detailed 3-d trajectory model).
- Airport departure and arrival rates .
- Sector capacity (or a penalty function?).
- Flight connectivity and turnaround time.
- Cost of delay/cancellation.

Model Description (Objective)

- Minimize
  - Total delay of all aircraft.
  - Weighted sum of ground and airborne delay.
  - Total gate-to-gate time.
  - Total passenger delay.
  - Sector overage.
  - Total system cost.

Model Description (Constraints)

- Sector capacity (hard/soft).
- Airport capacity (hard/soft).
- Flight connectivity.
- Min. and max. time of each aircraft in a sector.
- Max total delay per aircraft (cancellation).

Case Study : Aug 24, 2002 Data Sources

- Individual flights data: FAA - ASPM.
- Trajectory information: MIT - Lincoln Lab ETMS Radar Tracks.
- Preferred routes: FAA - CDR.
- Nominal sector capacity: FAA, NASA Ames.
- Weather coverage: MIT - Lincoln Lab CCFP CIWS.

Case Study : Aug 24, 2002

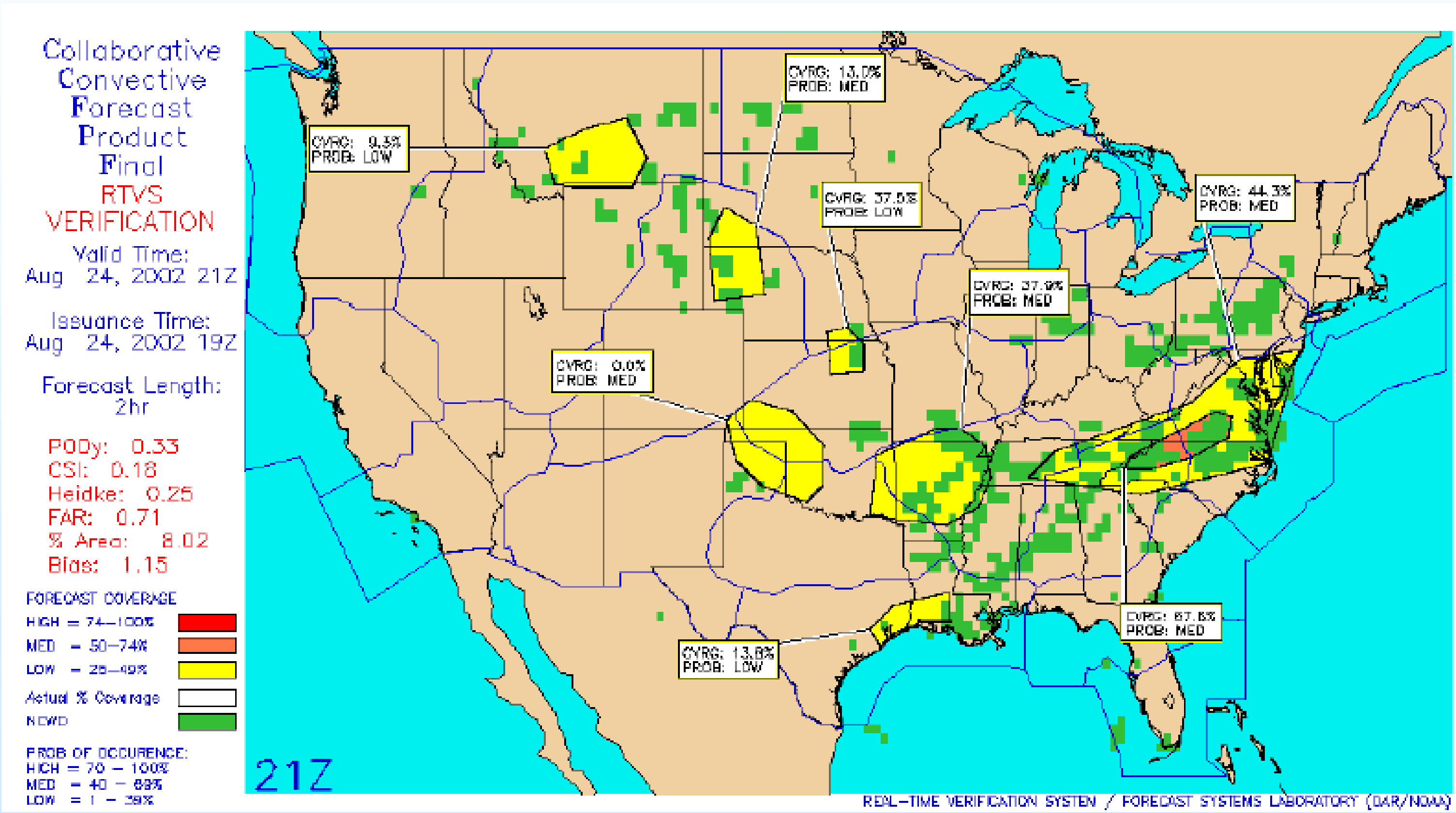

Figure 1. Severe weather over N-E United States

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Assumptions (Airports)

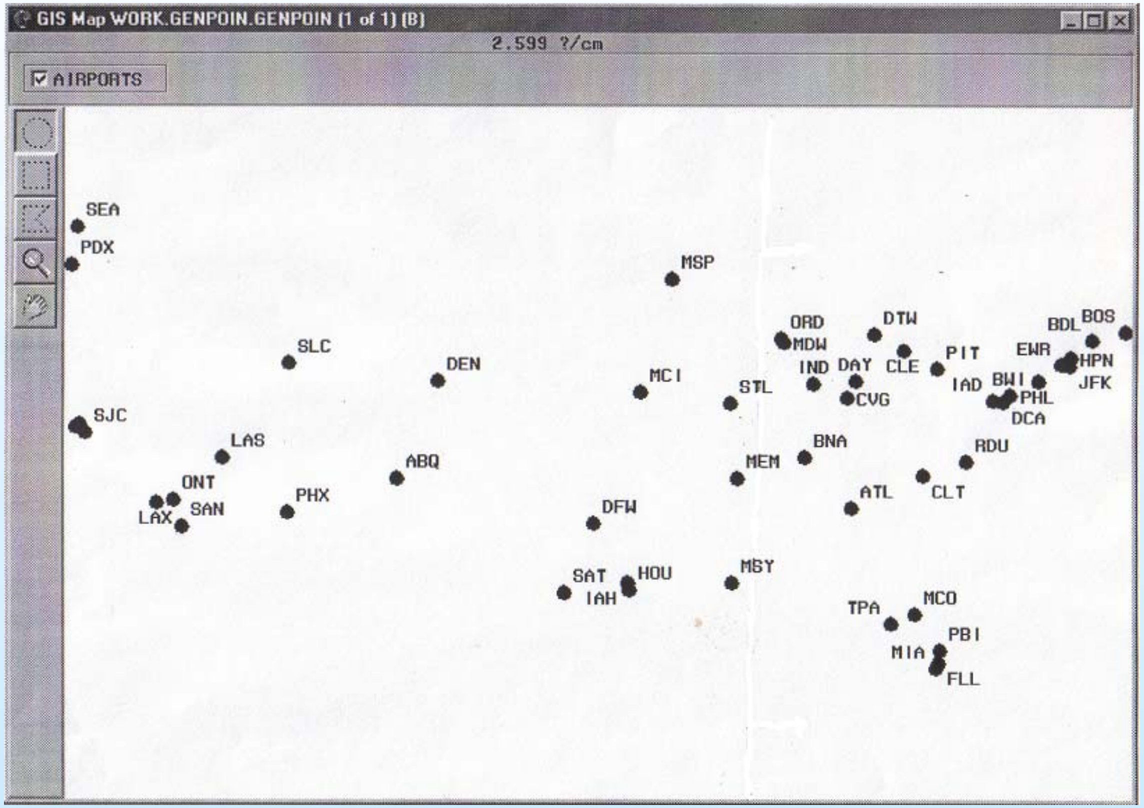
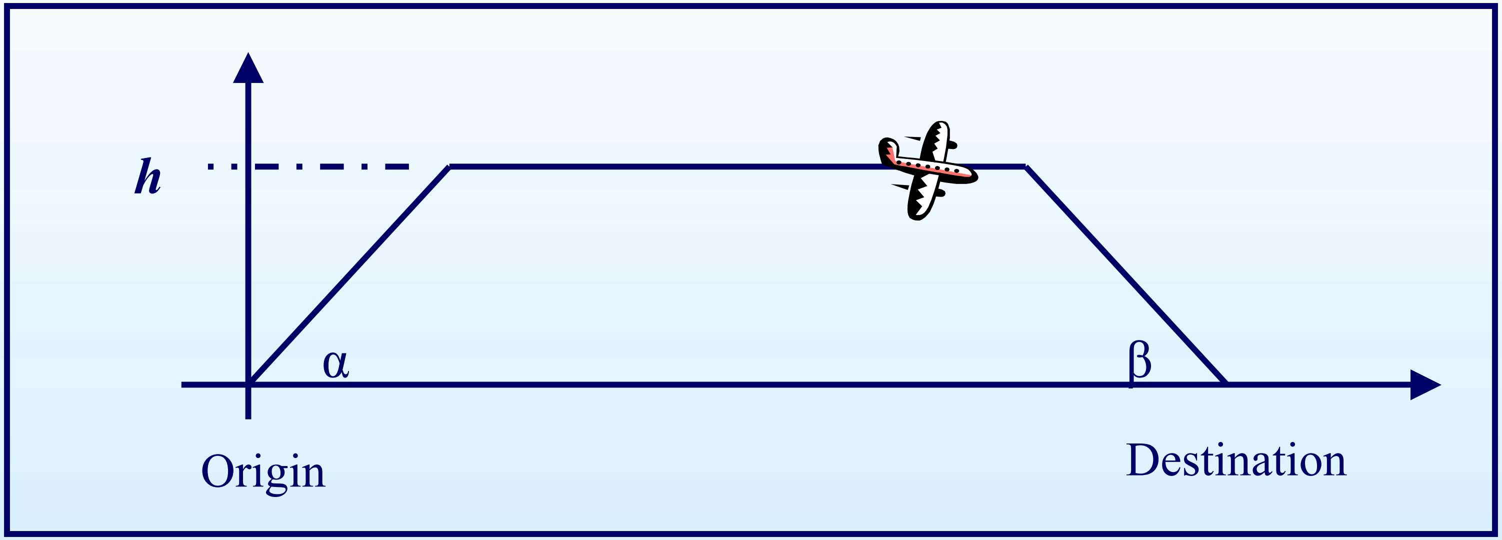


Figure 2. Subset of origin-destination pairs considered.

Assumptions (Flights)

- 2422 flights considered between major airports.
- Time: 1800-2400 Z.
- Flight plans chosen from Coded Departure Routes (CDR).
- Long-range flights considered separately and given priority.

Assumptions (Trajectory)



Parameters were estimated from trajectory data on a good-weather day. Parameters were assumed to be dependent on aircraft type and trip distance.

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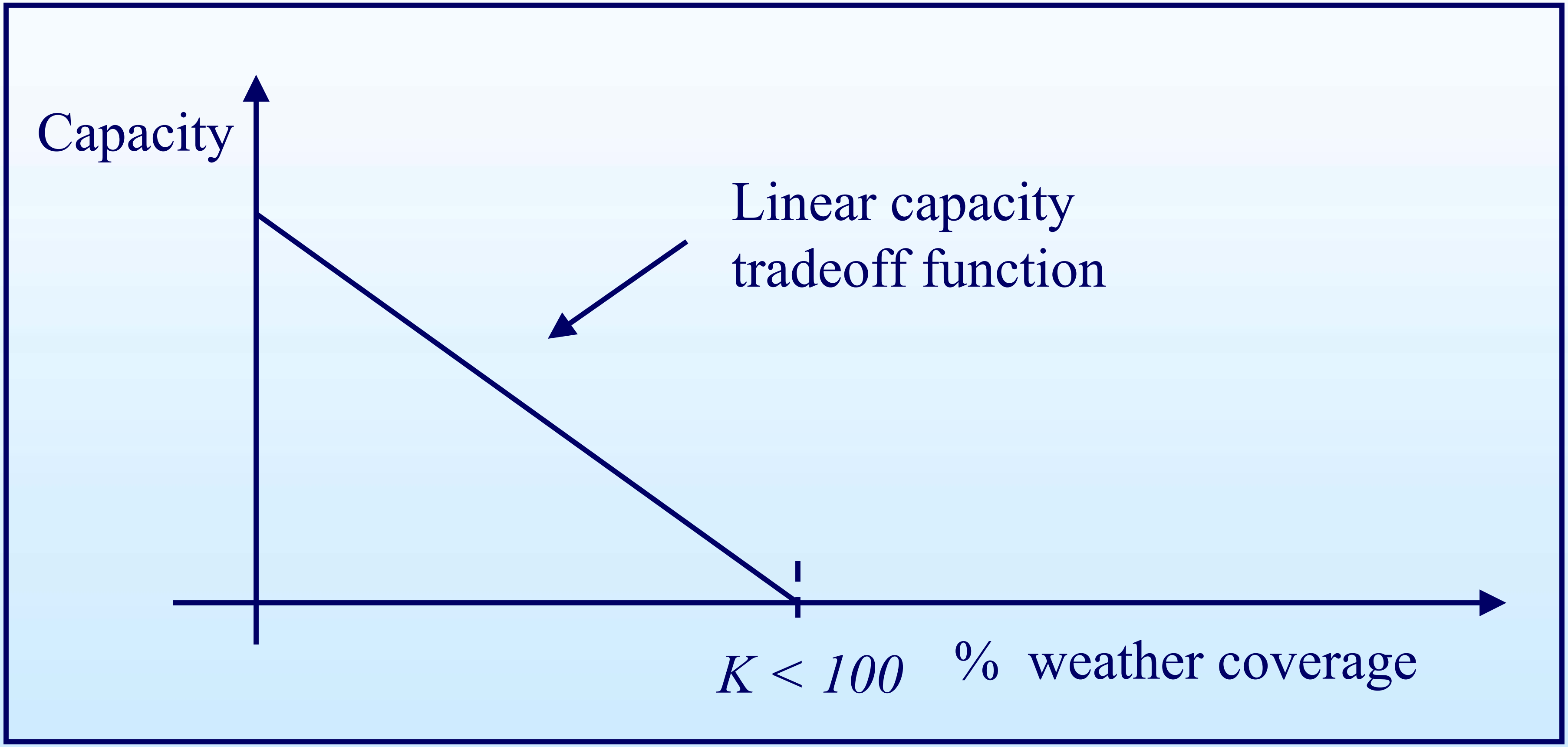
Assumptions (Capacity)



Results (shortest route only)

Metric	Actual	Model
Airborne time (Minutes)	194,000 (197,000 filed)	176,400
Delay/flight	0.62 min (-7.07 min on Aug 7)	4.4 min (3.6 min without connectivity)

Interesting: The model assigned NO airborne delay.

Additional Routes

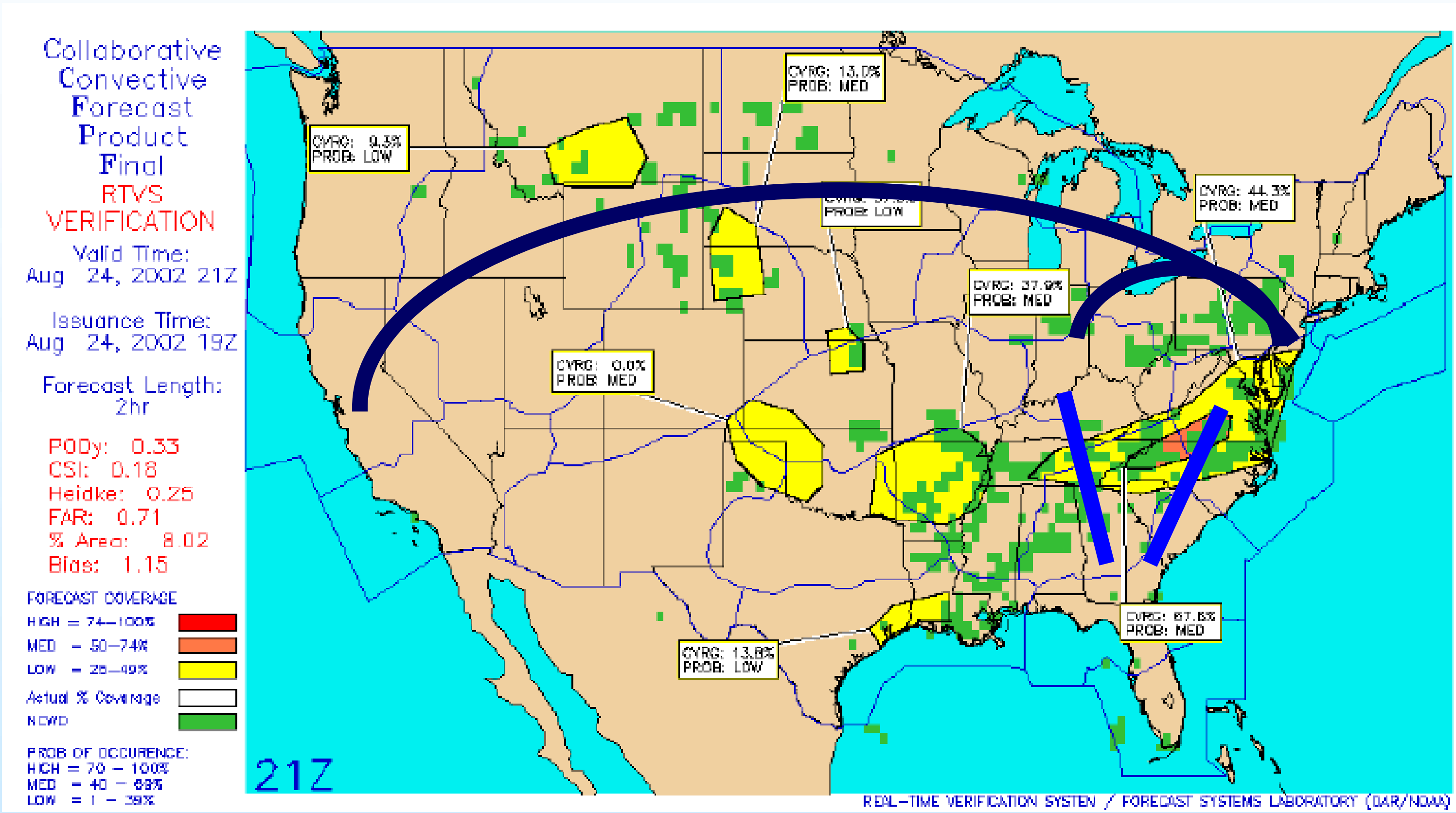


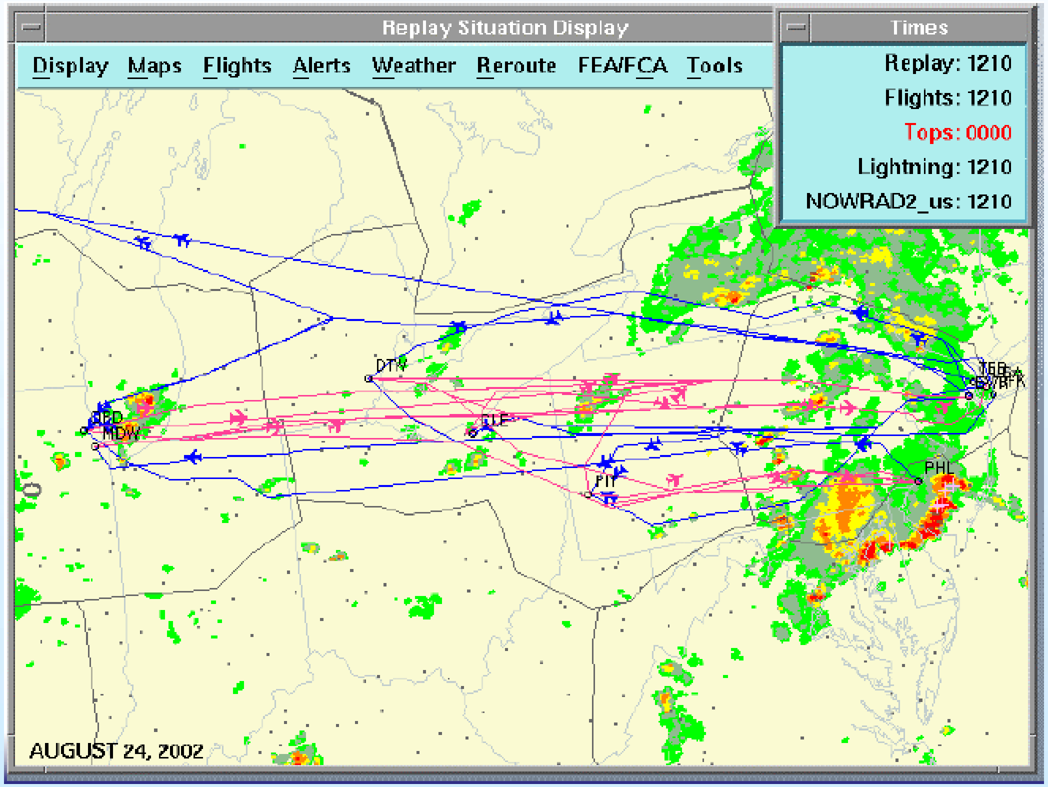
Figure 3. Added routes shown in black.

Results (multiple routes)

Metric	Model (single route)	Model (multiple routes)
Airborne time (Minutes)	176,400	177,900
Delay/flight	4.4 min (3.6 min without connectivity)	2.7 min (2.1 min without connectivity)

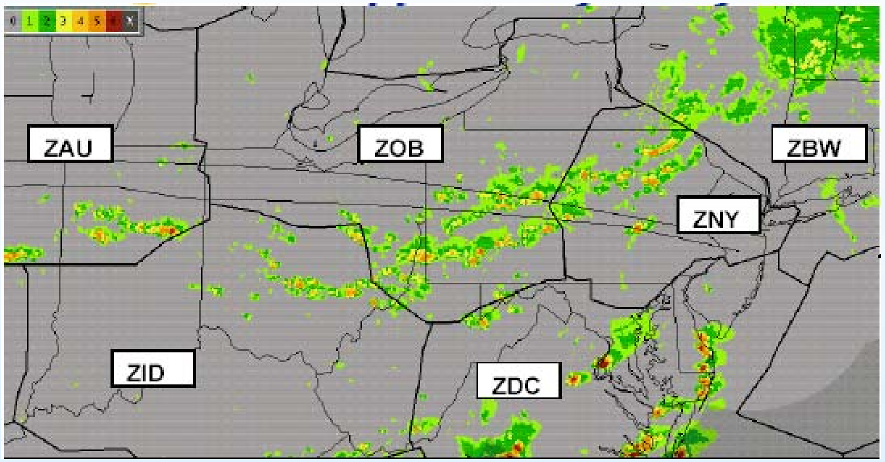
"Delay" for multiple routes is with respect to the flight time on the shortest path for that flight. Again, there was NO airborne holding.

Benefits Assessment of Echo-Tops



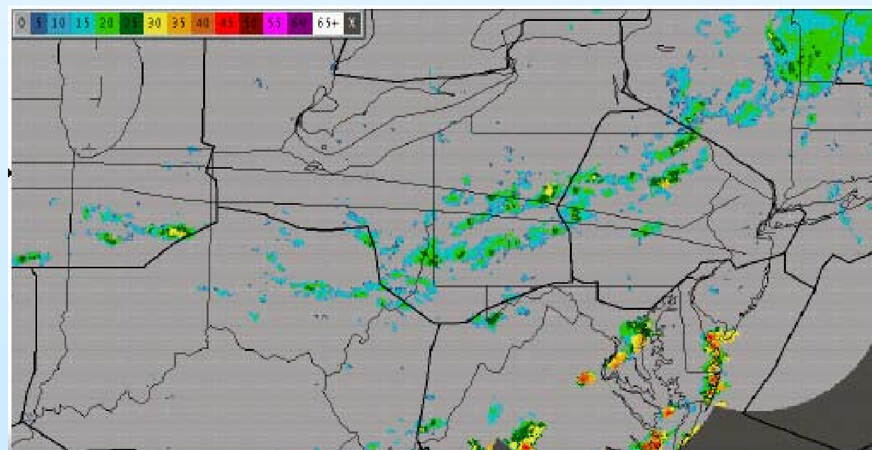
Aircraft appear to be using “blocked” sectors!

CIWS Echo-Tops Product



← NEXRAD

ECHO-TOPS →



Results (Echo-Tops Single Route)

Metric	Model (single route)	Model echo tops (single route)
Airborne time (Minutes)	176,400	176,400
Delay/flight	4.4 min (3.6 min without connectivity)	1.8 min (1.1 min without connectivity)

High and super high sectors were virtually unaffected.

Conclusions (1)

- It is now possible to answer several questions regarding the performance of the NAS on August 24th.
  - Decision support: What routes/delays should be assigned to flights to optimize operations (depending on metric)?
  - Benchmarking: How far were the operations from optimal (depending on metric)?
  - Schedule Evaluation: Is the given schedule feasible with full capacity?

Conclusions (2)

- Some more questions.
  - Benefits assessment: What are the benefits of providing echo-tops information to identify situations where aircraft can safely fly over storms? How much would you be willing to invest in it?
  - Network design: How would building an additional runway impact the traffic flows in the NAS?
  - Pricing mechanisms: What is the contribution of each aircraft to the total system cost? [Dual prices of LP give marginal utility of each additional unit of resource capacity and marginal cost of each aircraft to the system.]

Contributions of Study

- First application of the Bertsimas-Stock model to a large-scale real-world scenario.
- Cancellations explicitly modeled.
- Problem studied in three dimensions.
- Uses other than decision support were motivated.