

Interaction of Airspace Partitions and Traffic Flow Management Delay with Weather

Hak-Tae Lee

Gano B. Chatterji

University of California Santa Cruz

Kee Palopo

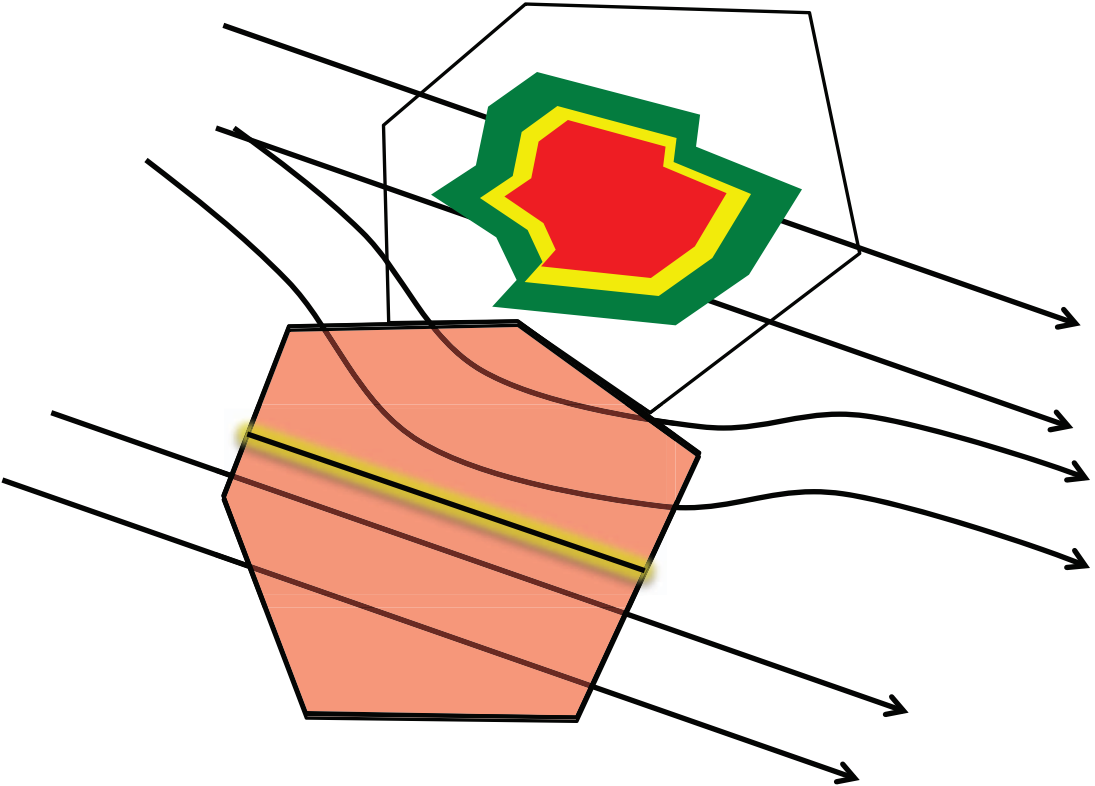
NASA Ames Research Center

Research Questions

How can traffic flow management and airspace partitioning work together to mitigate the impact of weather?

- What are the main causes of delay?
- Will repartitioning sectors help?
- How much capacity should be added?





Main Idea



Outline

- Approaches
- Analysis Tools and Simulation
- Results
- Conclusions

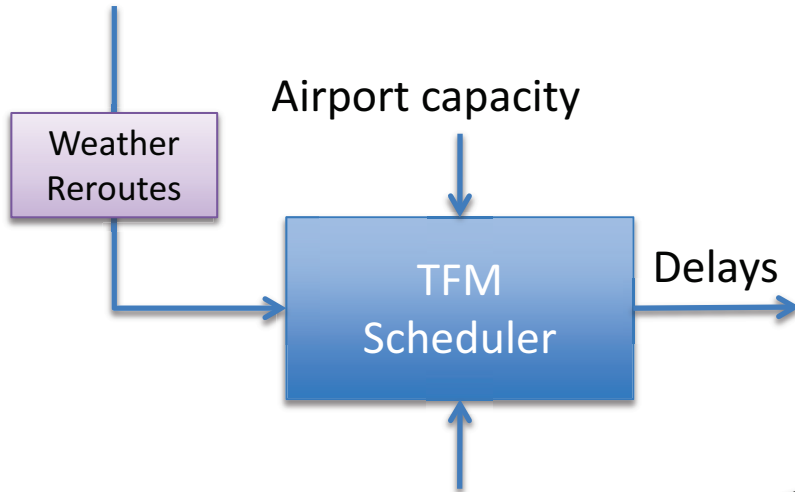
Approaches

| | Airport | Airspace |
|------------|---|---|
| Method I | Traffic Flow Management (TFM)  | TFM |
| Method II | TFM  | Partitioning |
| Method III | TFM  | Partitioning  TFM |

Method I

TFM

Unconstrained
schedule



Airport capacity

Weather
Reroutes

TFM
Scheduler

Delays

Sector capacity

Sector geometry

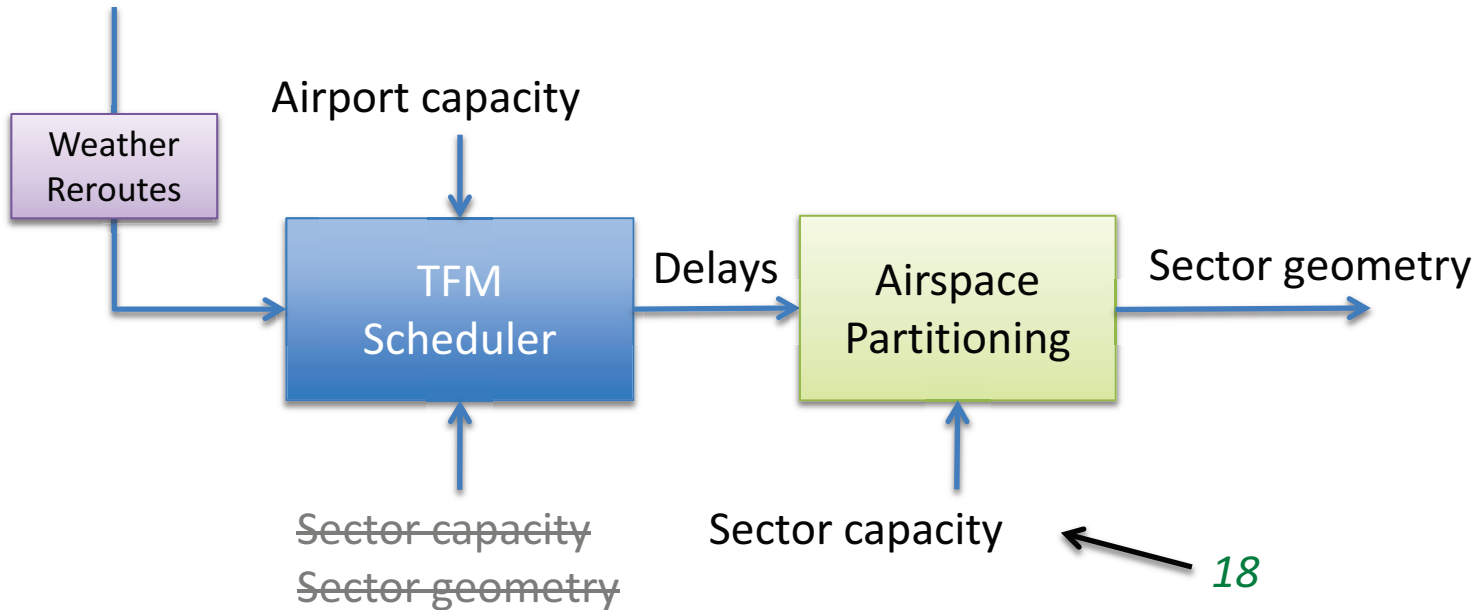
18

Based on clear weather day traffic

Method II

TFM → Partitioning

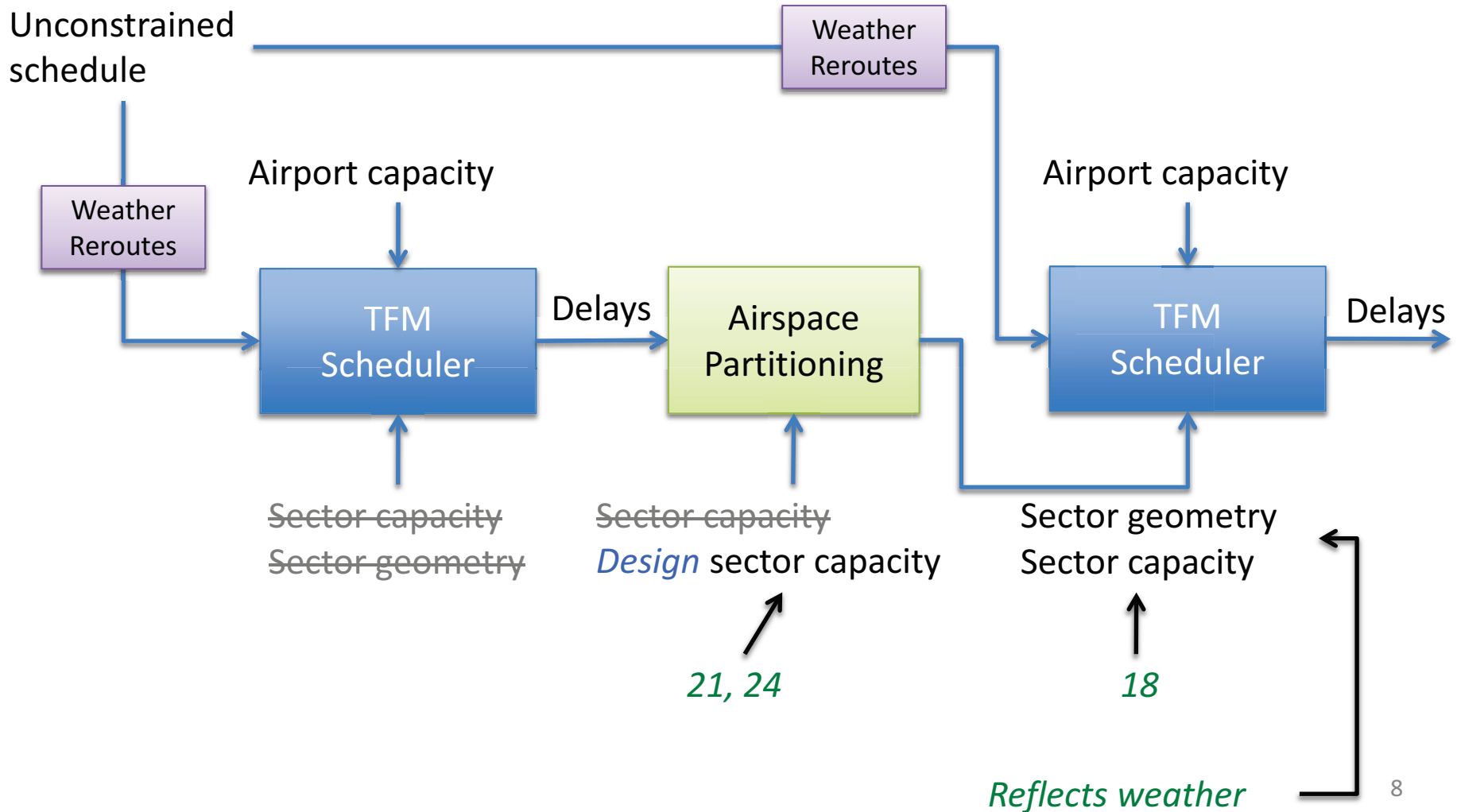
Unconstrained
schedule



18

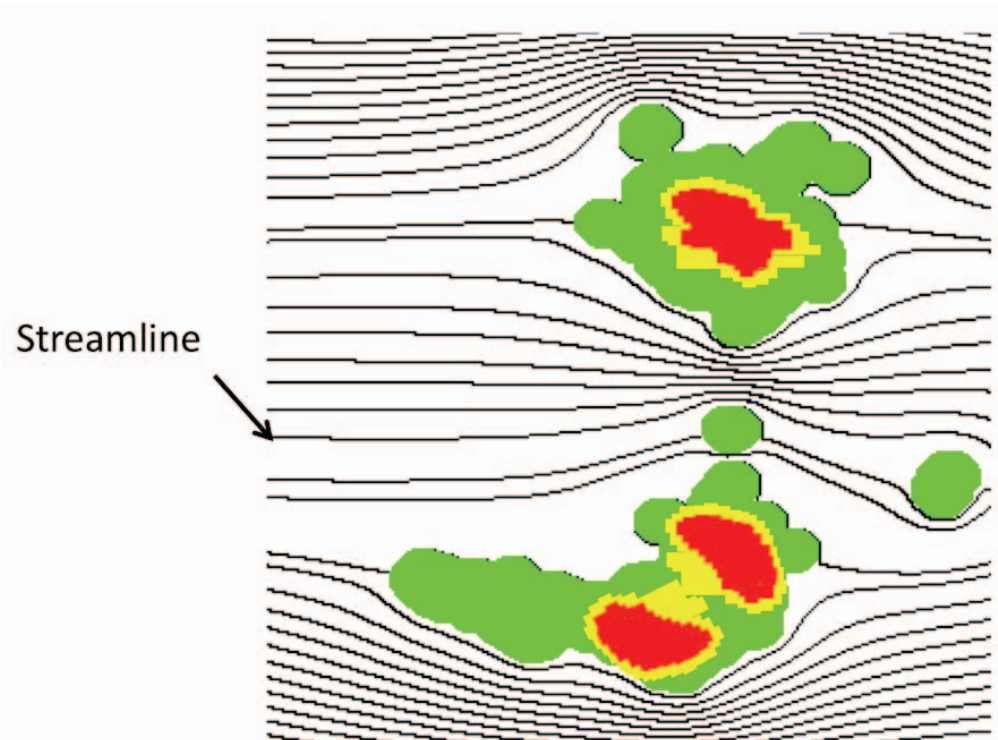
Method III

TFM → Partitioning → TFM



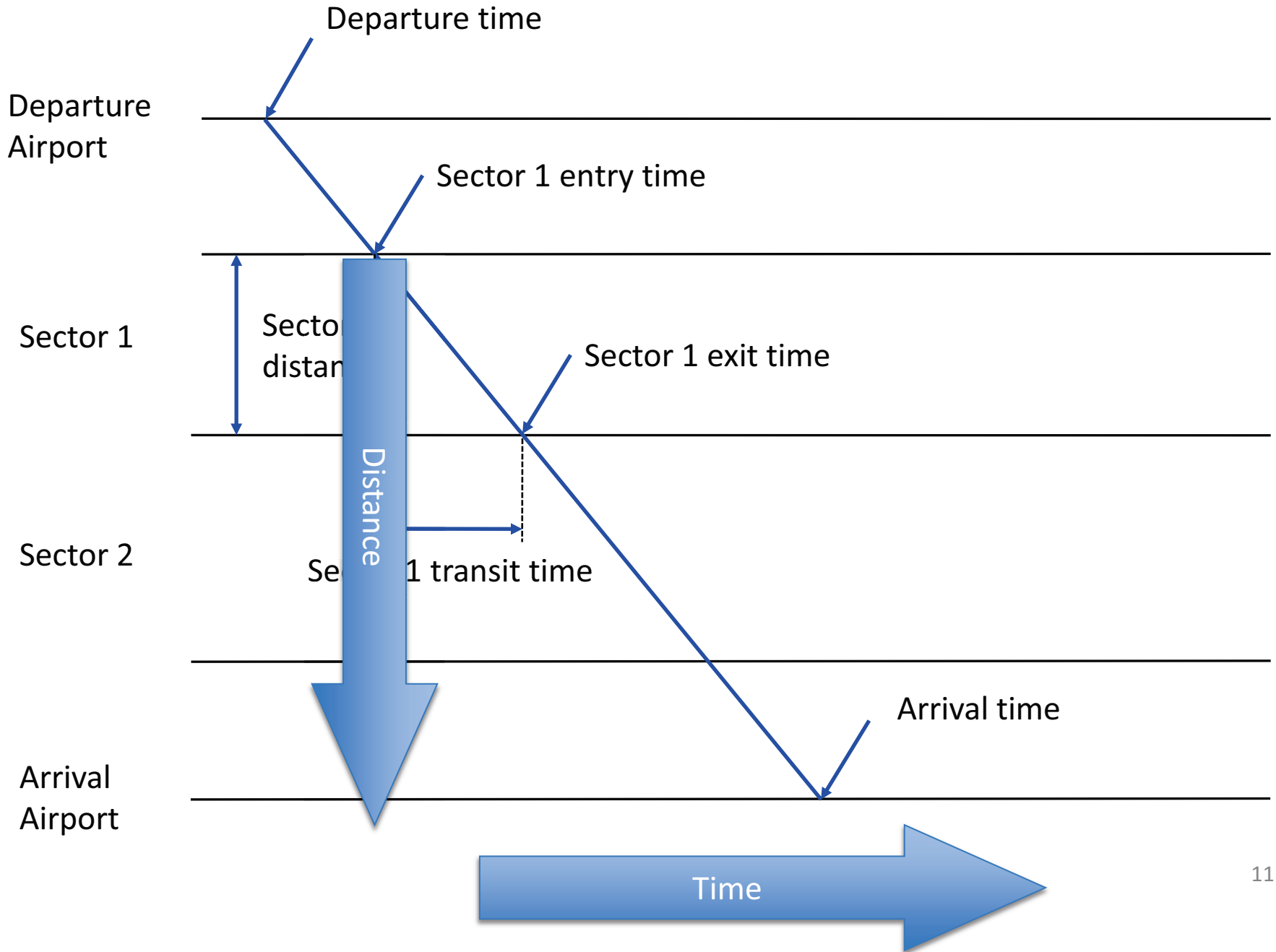
Weather Rerouting

- Generate flight routes that avoid convective weather
 - Level 3 and above
 - Infinite tops
- Streamline
 - Smooth
 - Family of routes



Traffic Flow Management

- Delay departure and change route to satisfy capacity constraints
 - Airports : departure and arrival rates
 - Airspace : maximum number of aircraft
- FCFS Scheduler
 - Based on “A Closed-Form Solutions to Multi-Point Scheduling Problem” (Larry Meyn, 2010)
 - First-Come First-Served by departure time
 - Aircraft can speed up/slow down

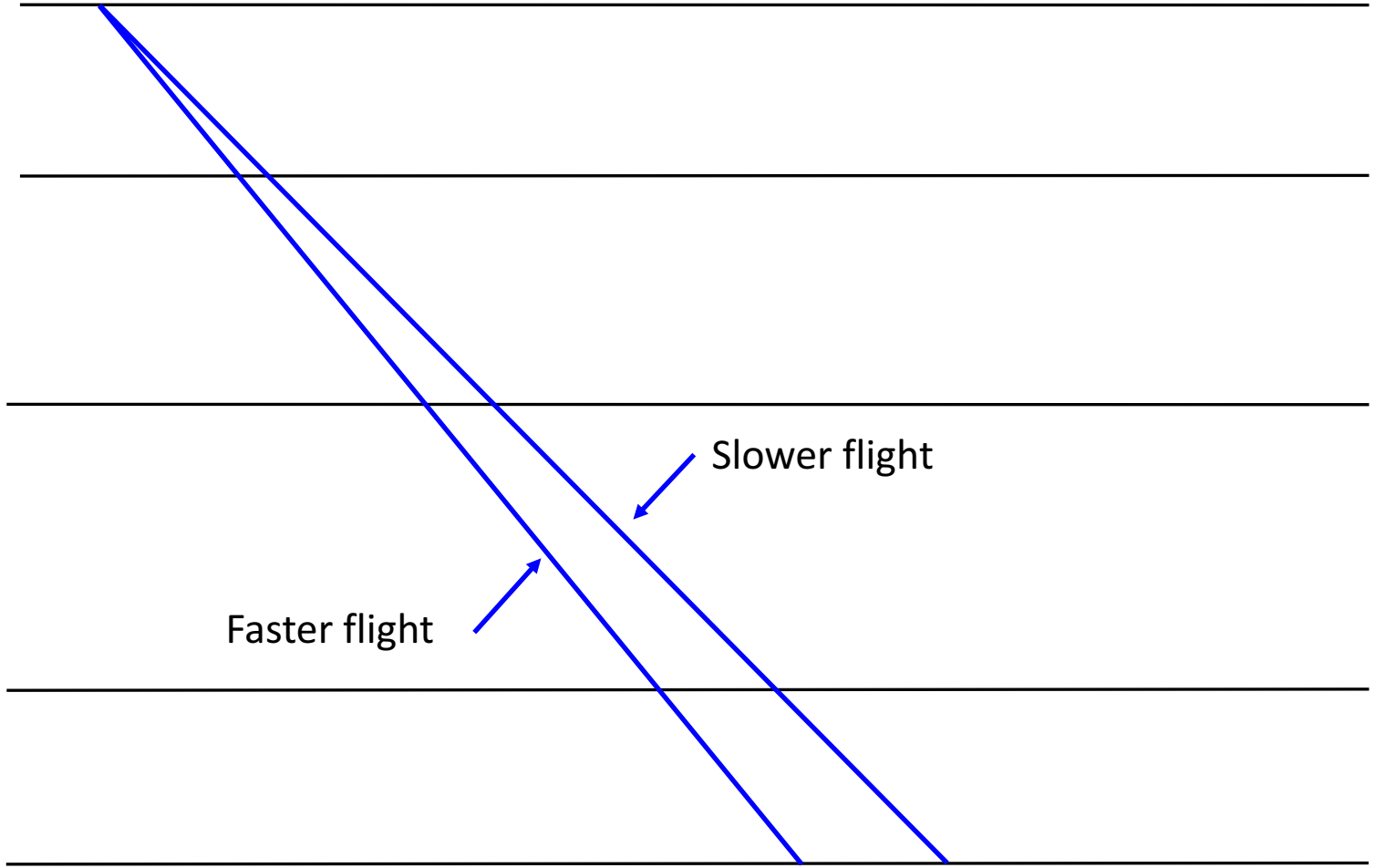


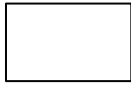
Departure
Airport

Sector 1

Sector 2

Arrival
Airport



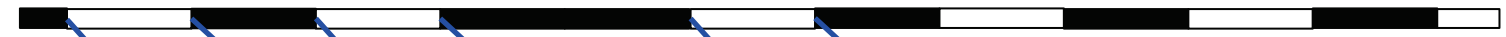


Available slot

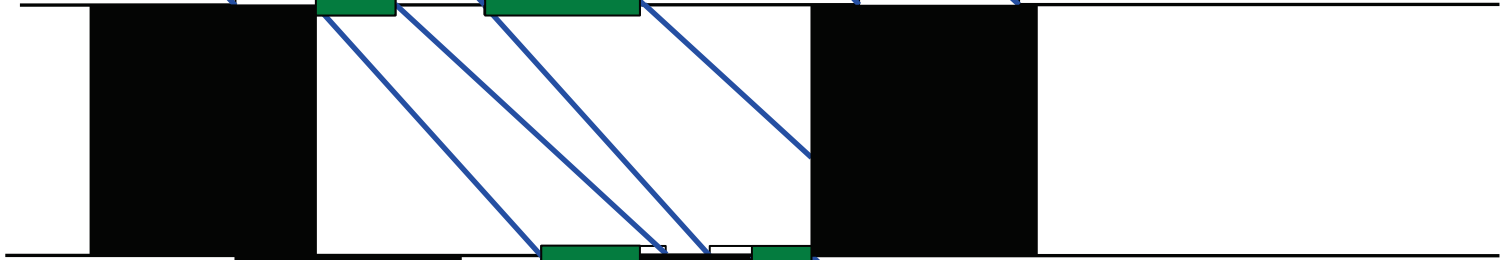


Unavailable slot

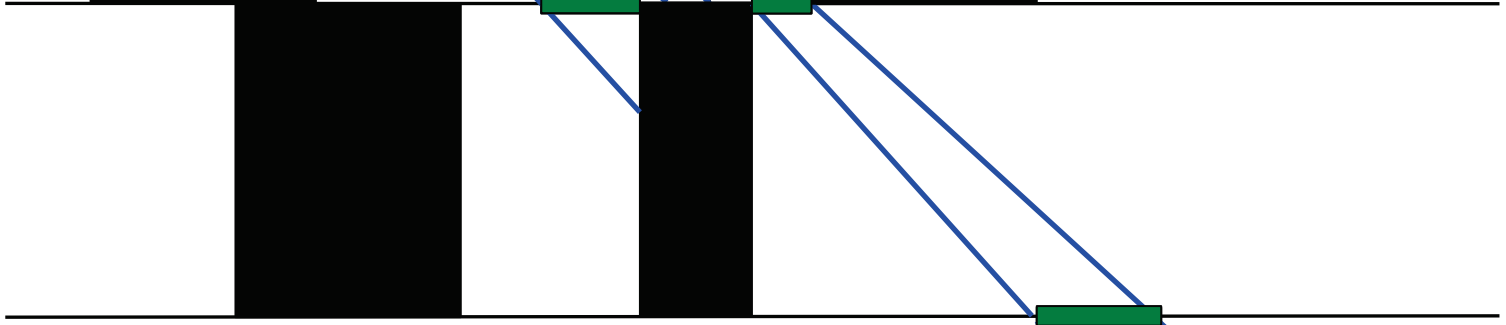
Departure
Airport



Sector 1



Sector 2

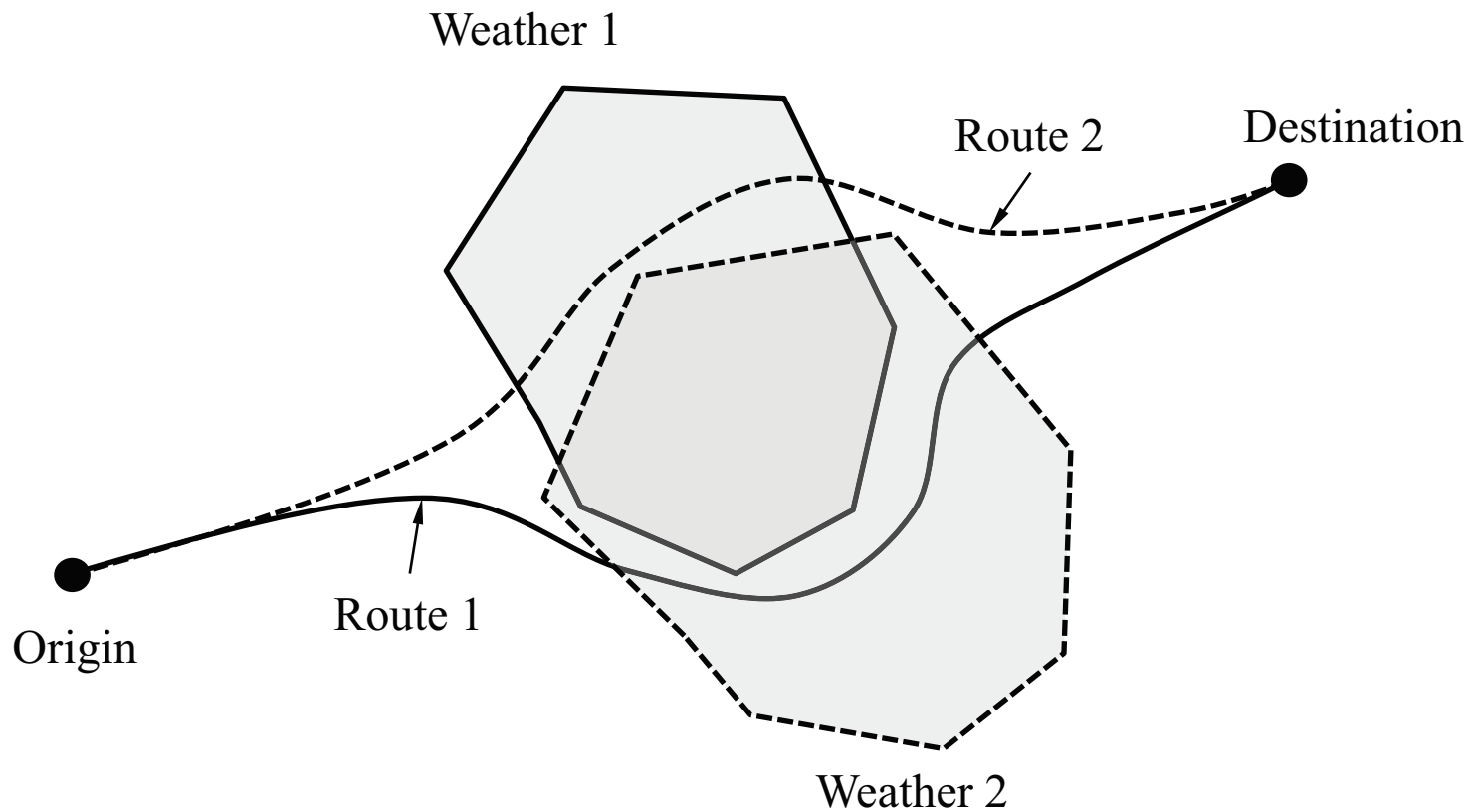


Arrival
Airport



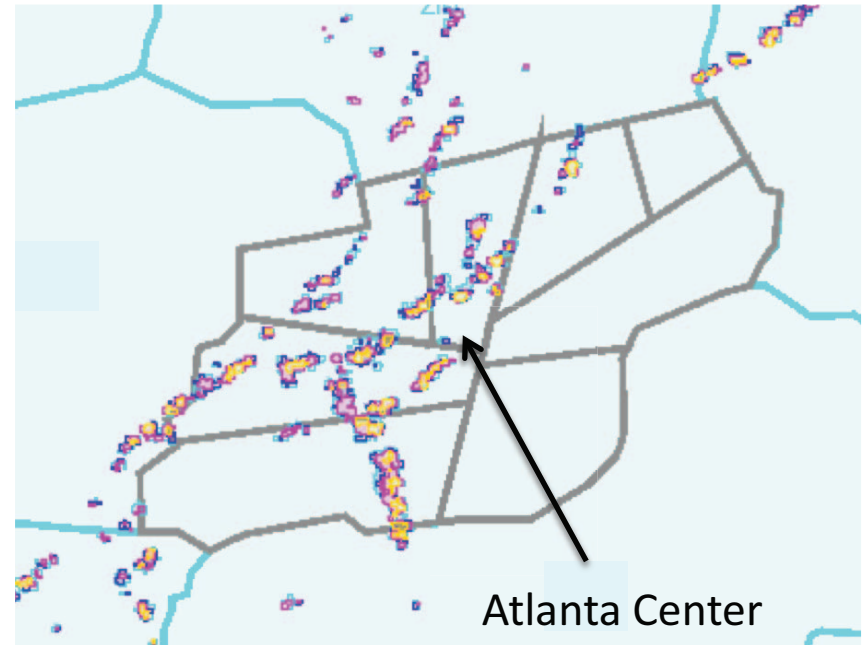
↑ Earliest Arrival

Interaction between Routes and Scheduling



Airspace Partitioning

- Generate airspace partitions (Sectors) from aircraft tracks
 - Voronoi diagram-based
 - Min Xue, 2009
- Optimization setup
 - Variables
 - Control points
 - Vertical slice
 - Objectives
 - Dwell time
 - Flow placement
 - Boundary crossings
 - Constraint
 - Maximum number of aircraft



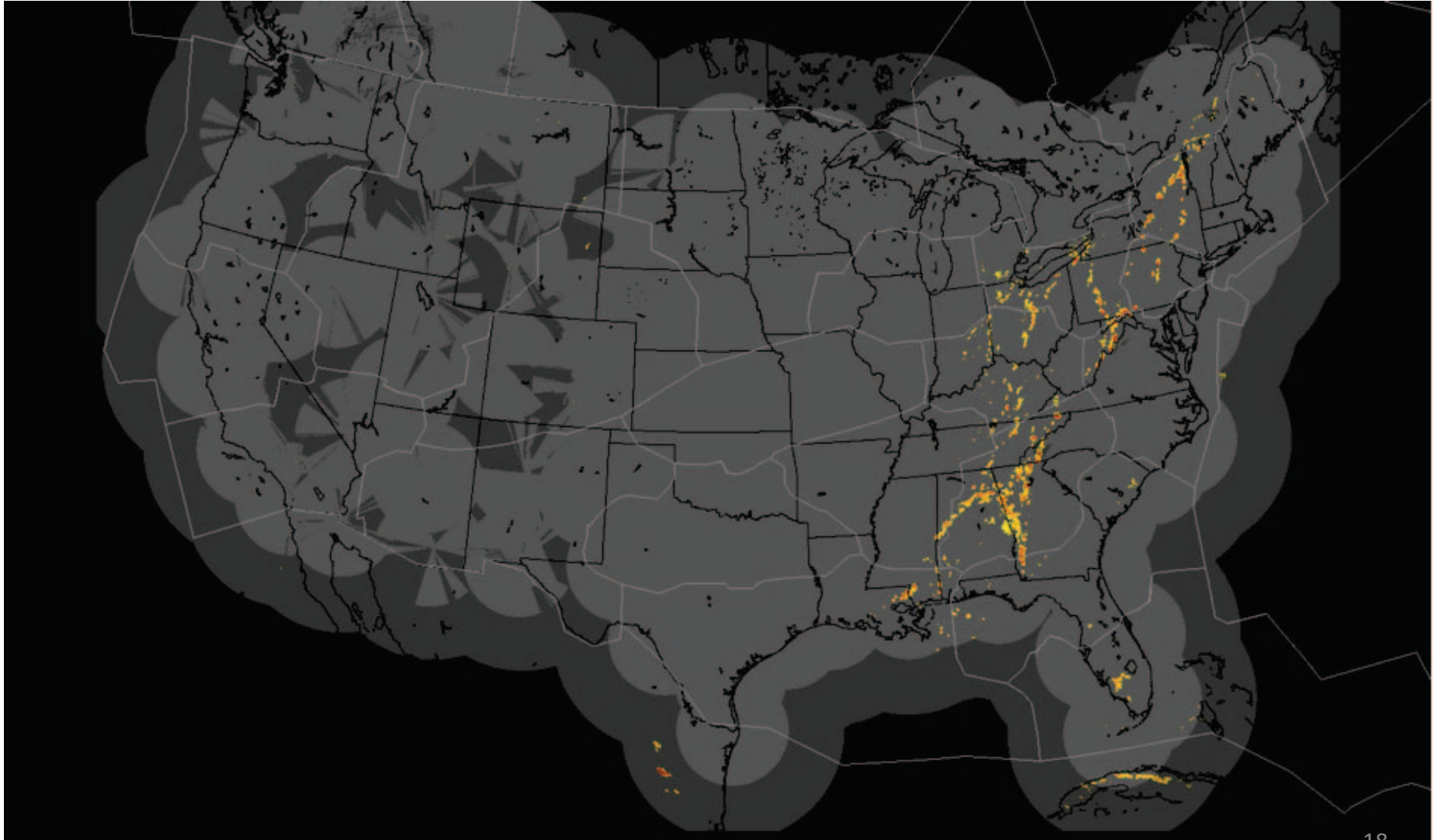
Air Traffic Simulation

- Airspace Concept Evaluation System
 - Gate-to-gate air traffic simulation tool
 - Developed at NASA Ames Research Center
- For this study,
 - Scheduling: airport departure/arrival sector entry/exit times
 - Partitioning: aircraft tracks

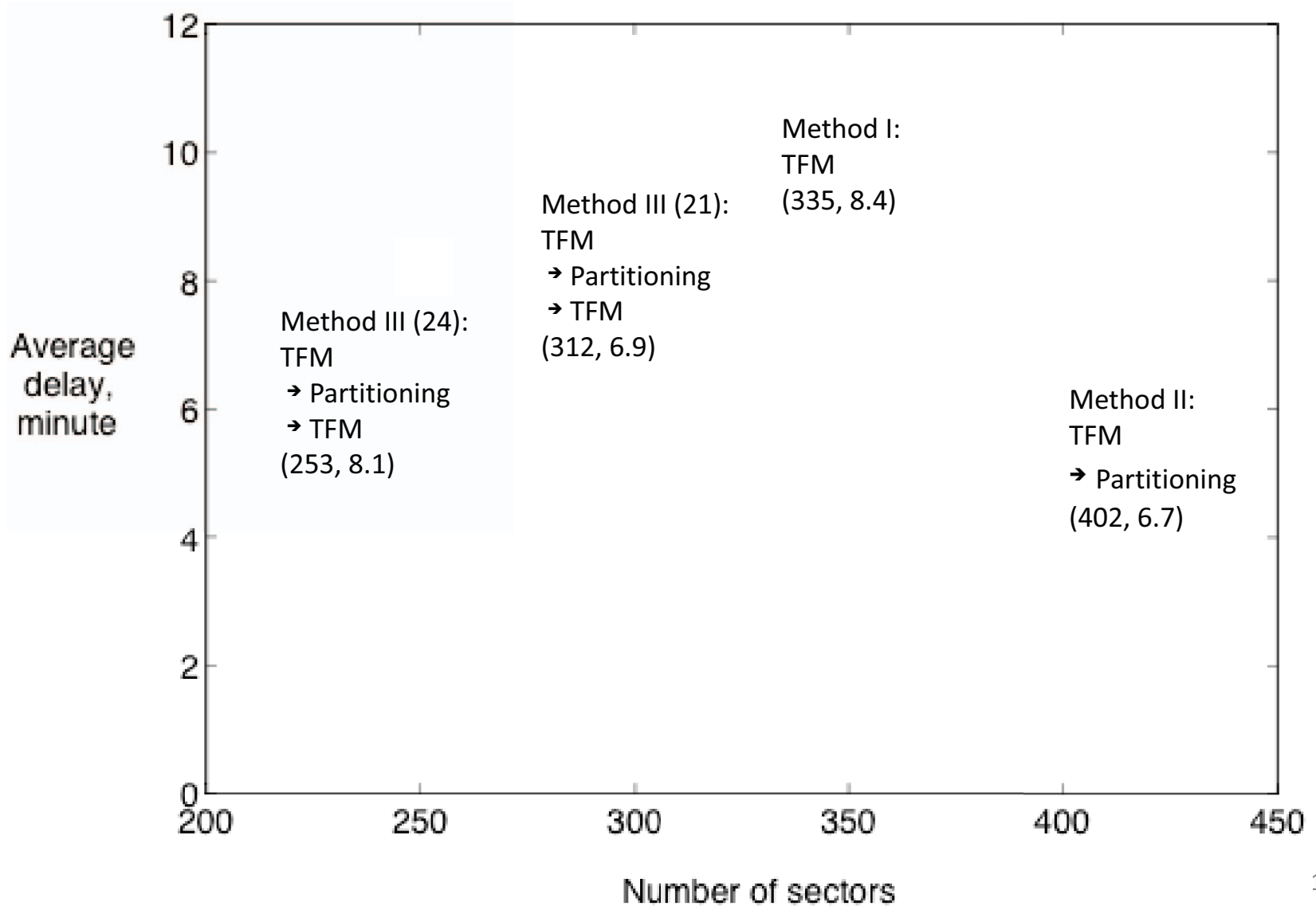
Simulation Setup

- Simulation day: May 3rd, 2007
 - Clear weather day
 - High volume traffic (48,000 flights)
 - Full day simulation
- Simulation scope
 - Continental US
 - High altitude sectors only (above 24,000 ft)
- Convective weather: May 26th, 2011
 - Severe weather over east coast
 - Deterministic weather

Convective Weather



Results



Conclusions

In this study,

- Weather caused delays can be reduced by re-partitioning to a certain extent.
- Traffic flow management and partitioning together achieve the best combination of both lowest average delays and number of sectors.