TURKISH AVIATION ACADEMY

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Delay Propagation in the Air Transportation Network

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Strategic Planning

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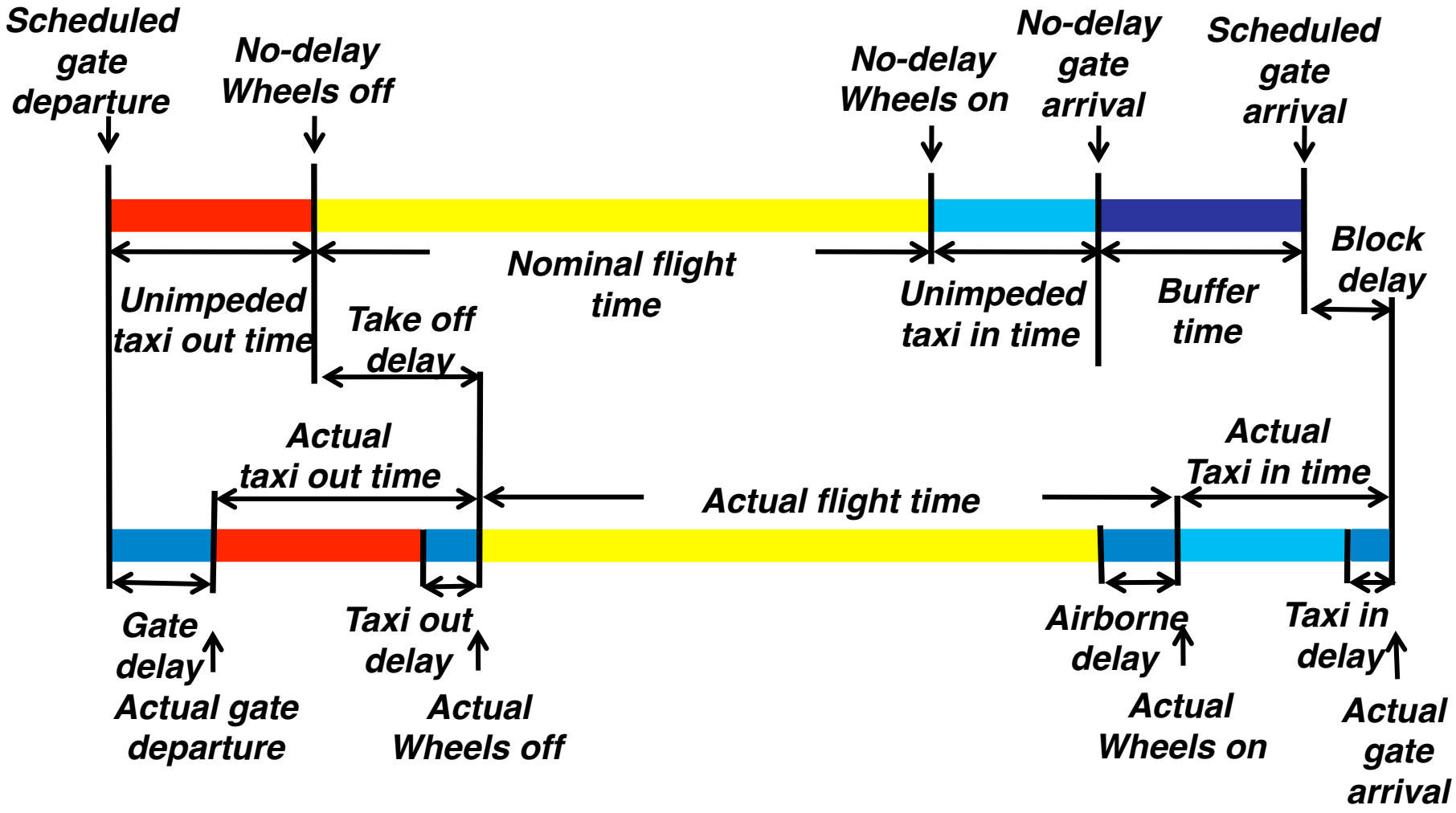
Causes of flight delays

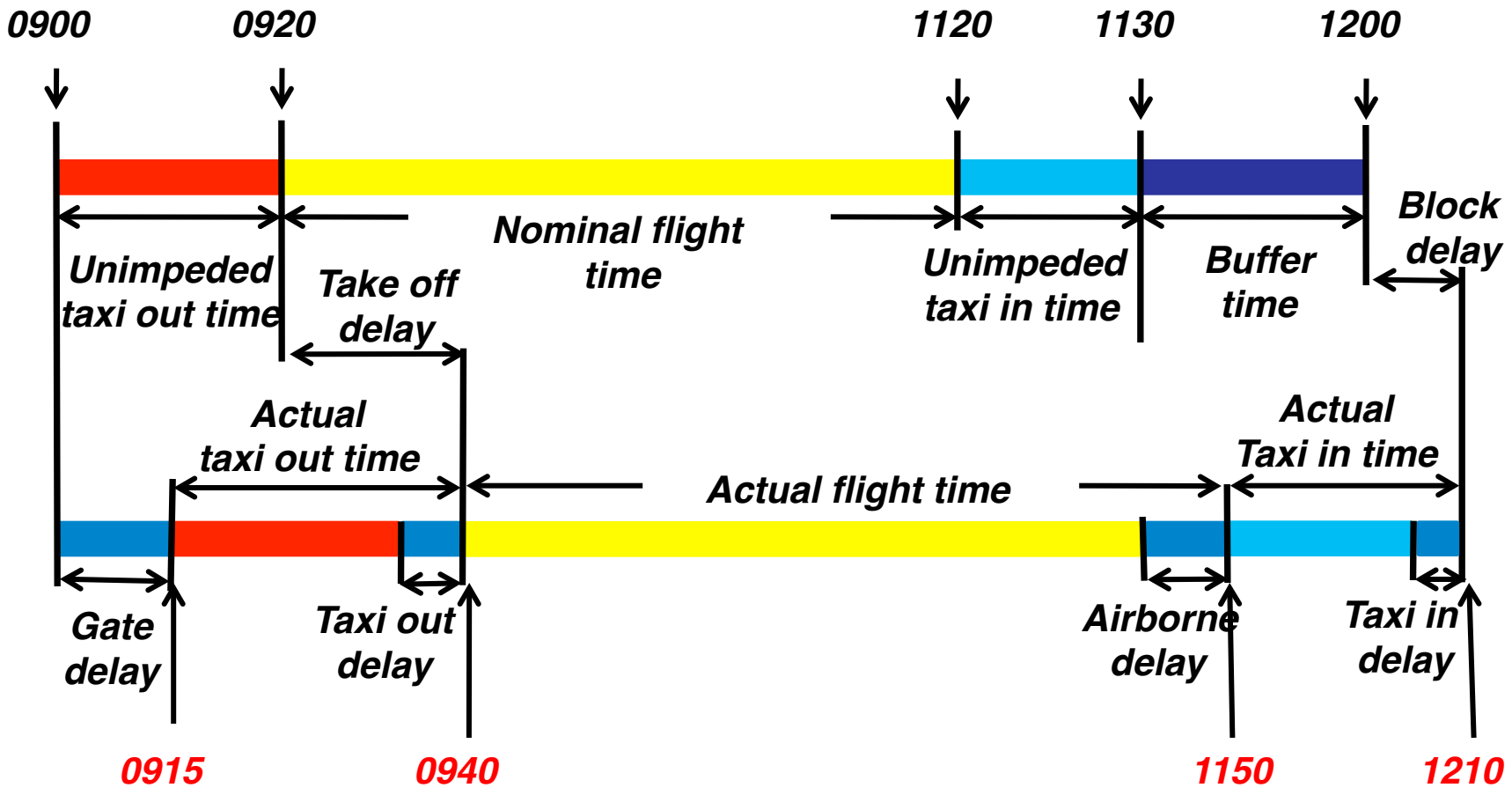
- **Departure**
  - Unavailable aircraft
  - Unavailable crew
  - Ground holds/Ground Delay Programs
- **Taxi-out**
  - Weather
  - Congestion
- **Flight time**
  - Congestion
  - Weather
- **Taxi-in**
  - Congestion
  - Weather
  - Gate blockage

Operational variability and flight delays



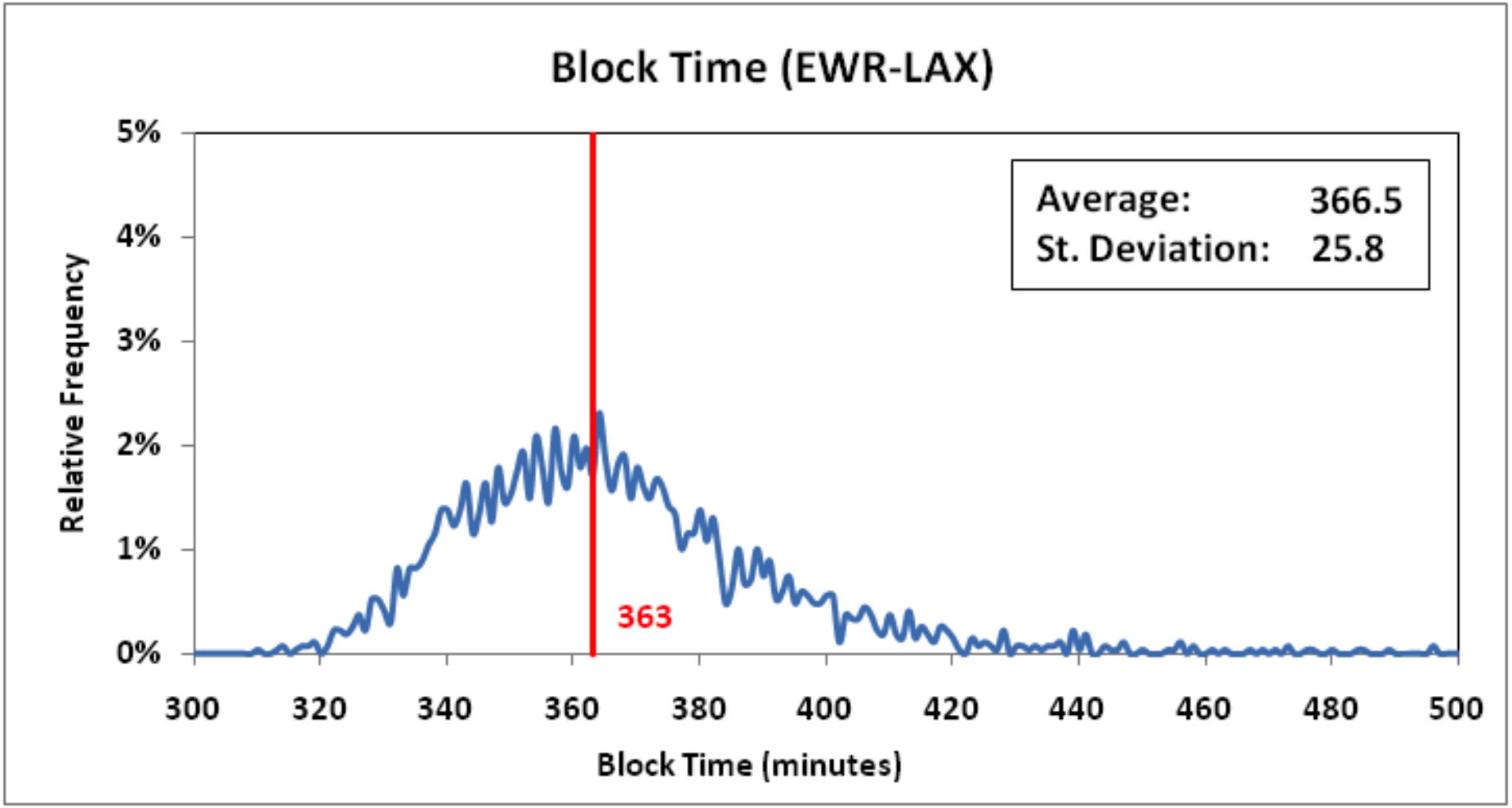
Source: Gerasimos Skaltsas, MIT

Example: Planned vs. Actual flight times



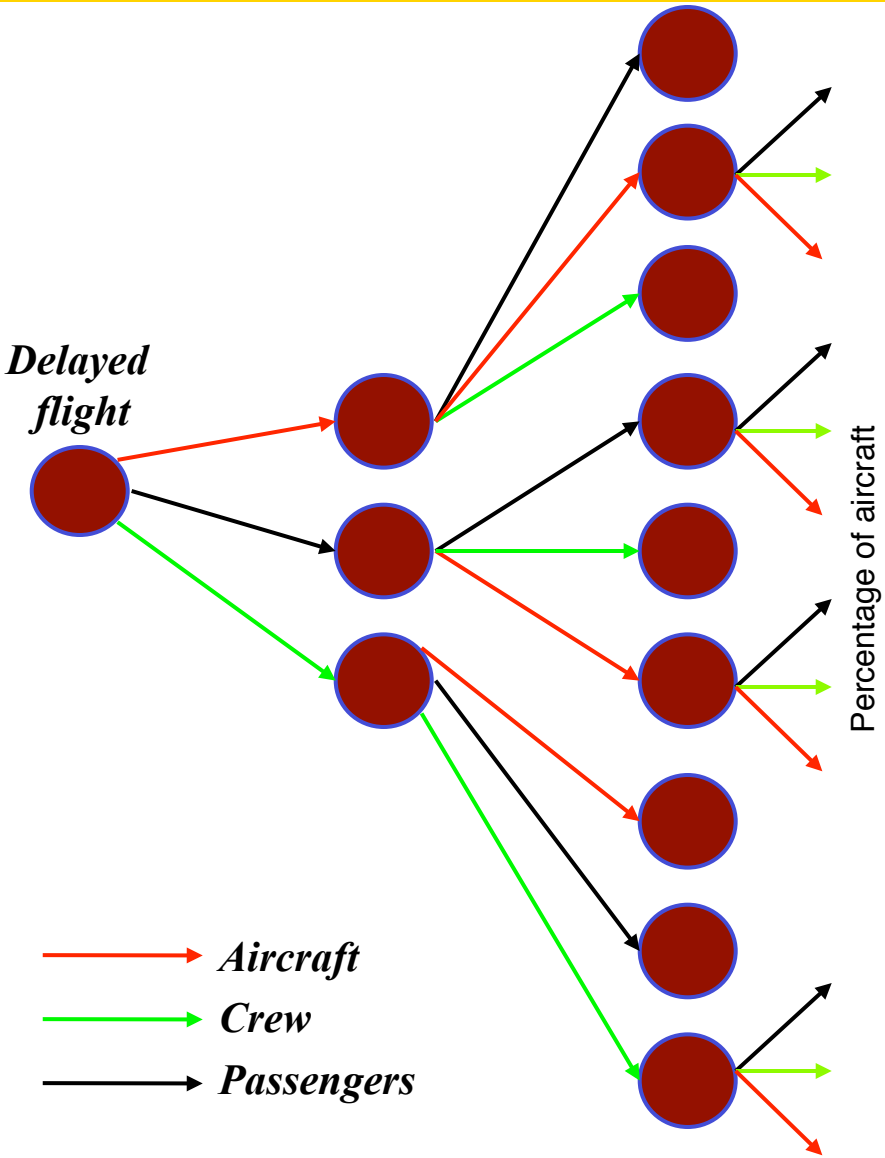
Source: Gerasimos Skaltsas, MIT

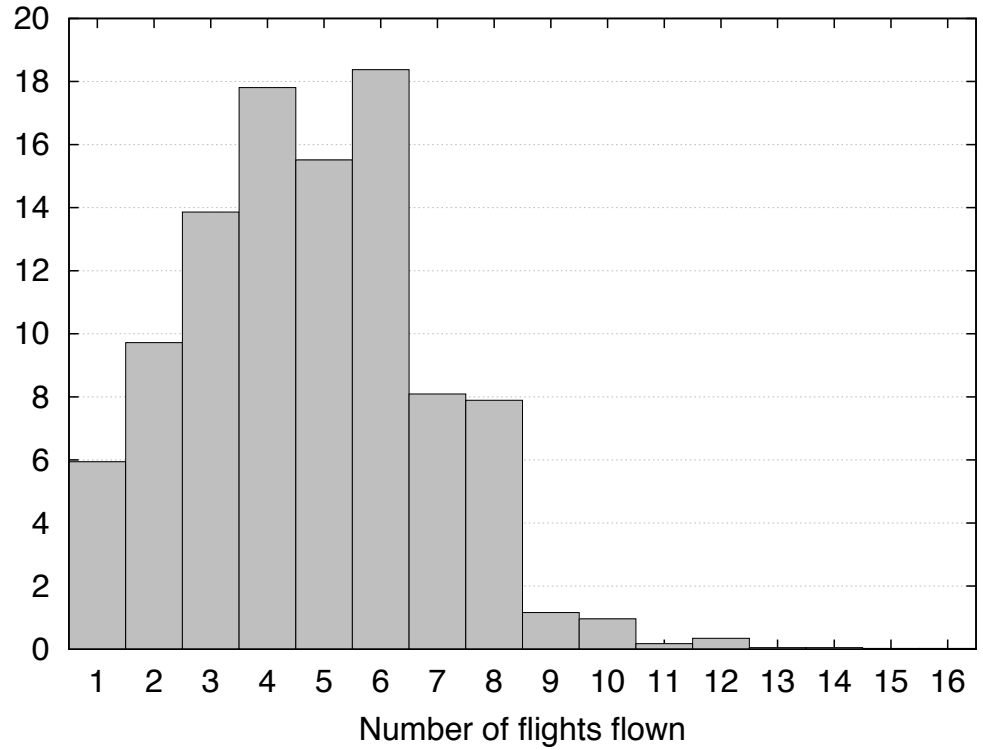
Variability in actual block times



Source: Gerasimos Skaltsas; Prof. Peter Belobaba

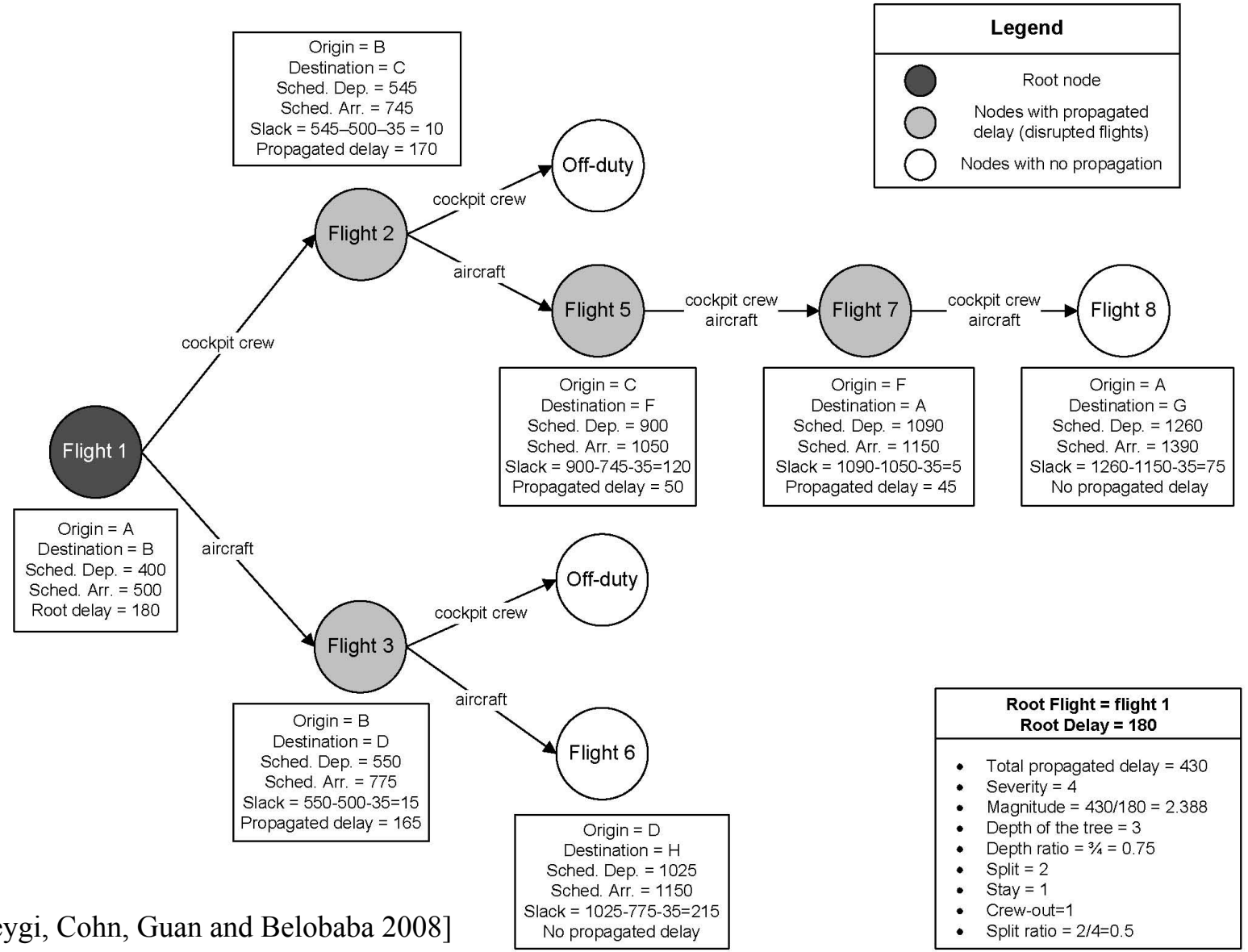
Aircraft, crew and passengers connect





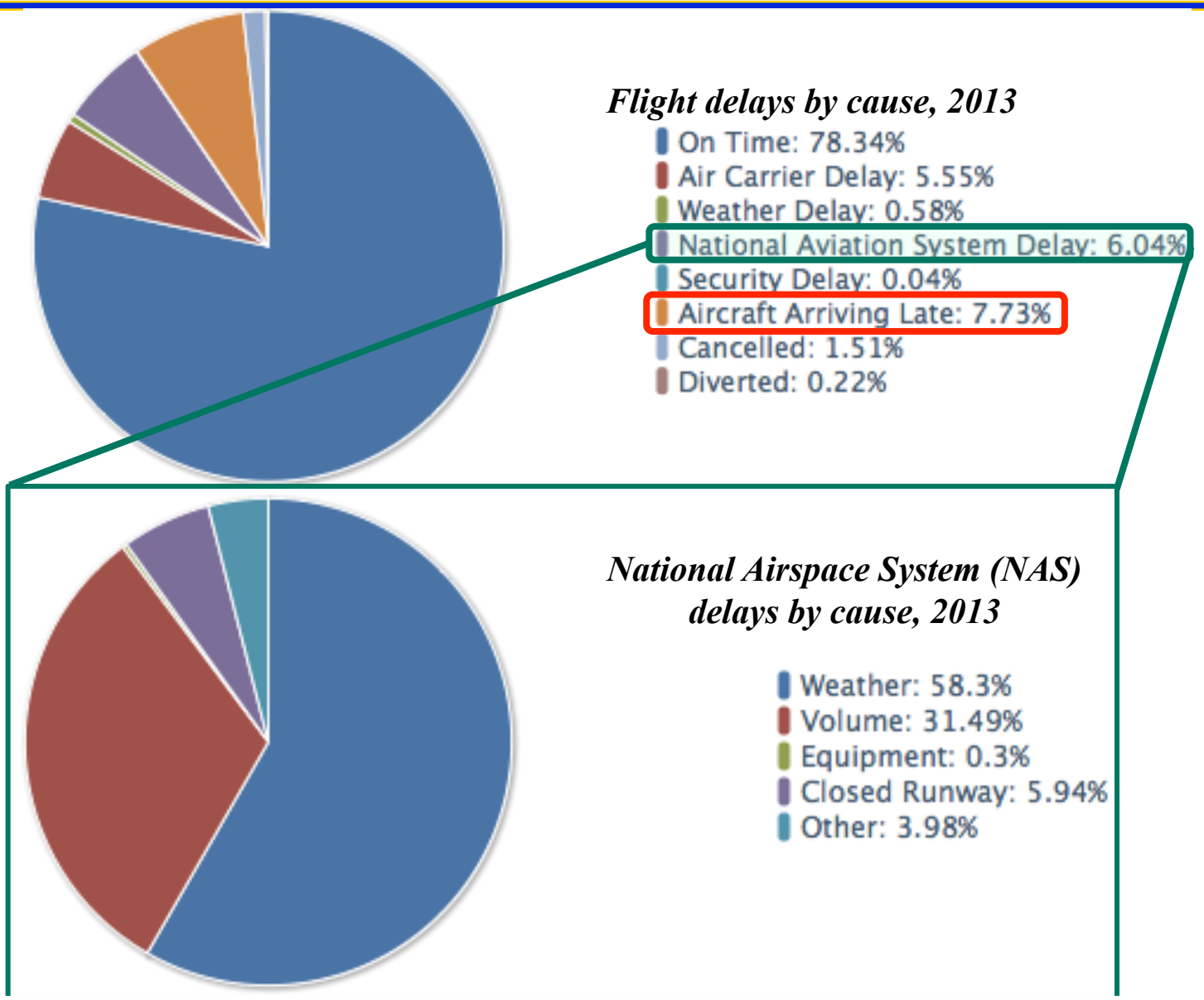
[Balakrishnan and Chandran, 2014]

These connections lead to delay propagation



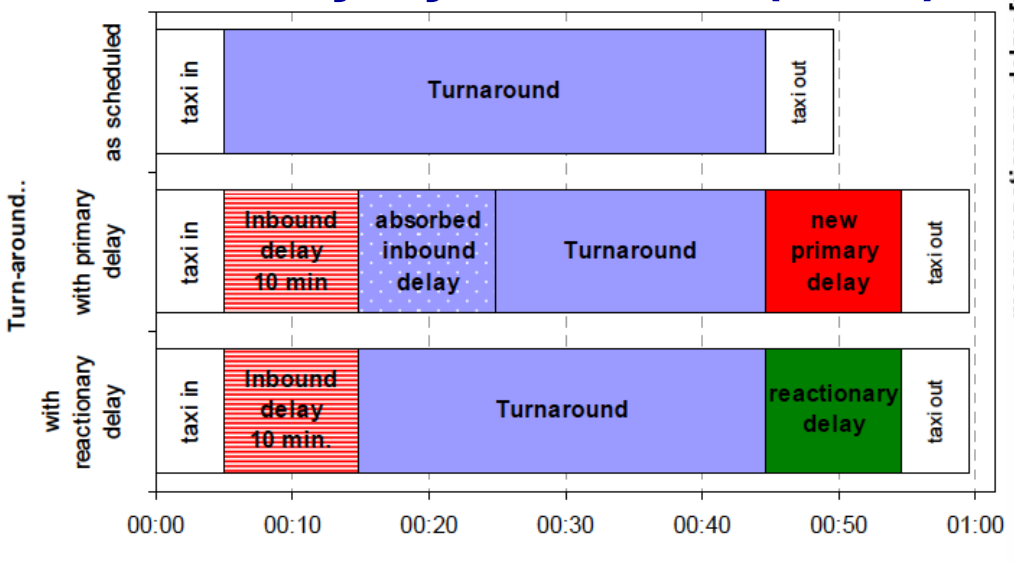
[AhmadBeygi, Cohn, Guan and Belobaba 2008]

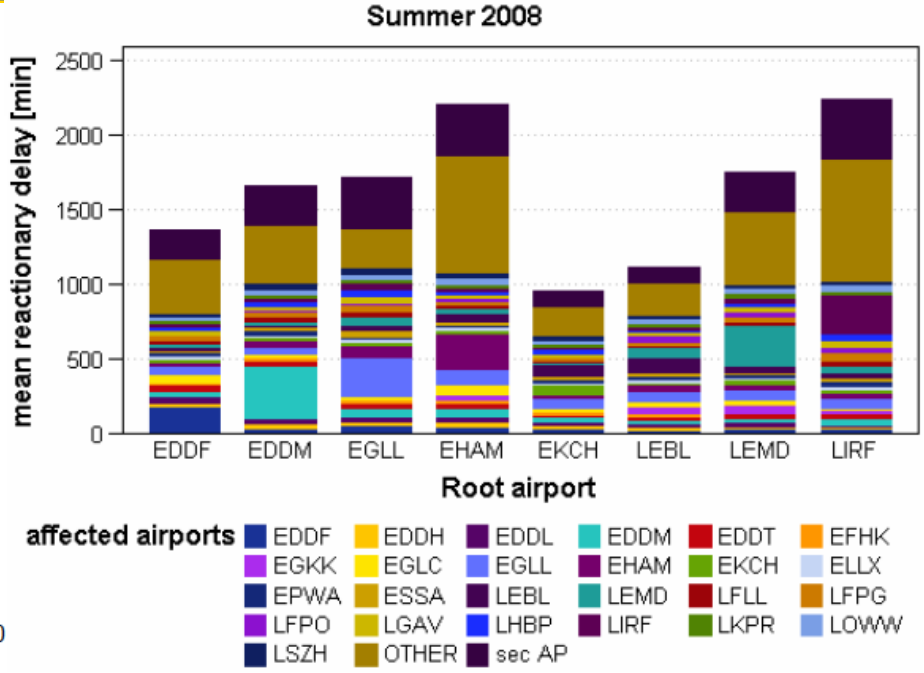
Causes of flight delays

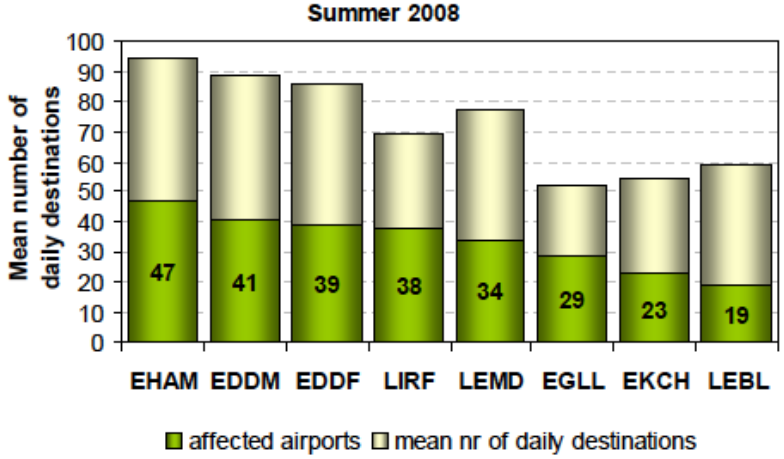


Estimating extent of flight delay propagation in Europe

- **Study by M. Jetzki (2009)**



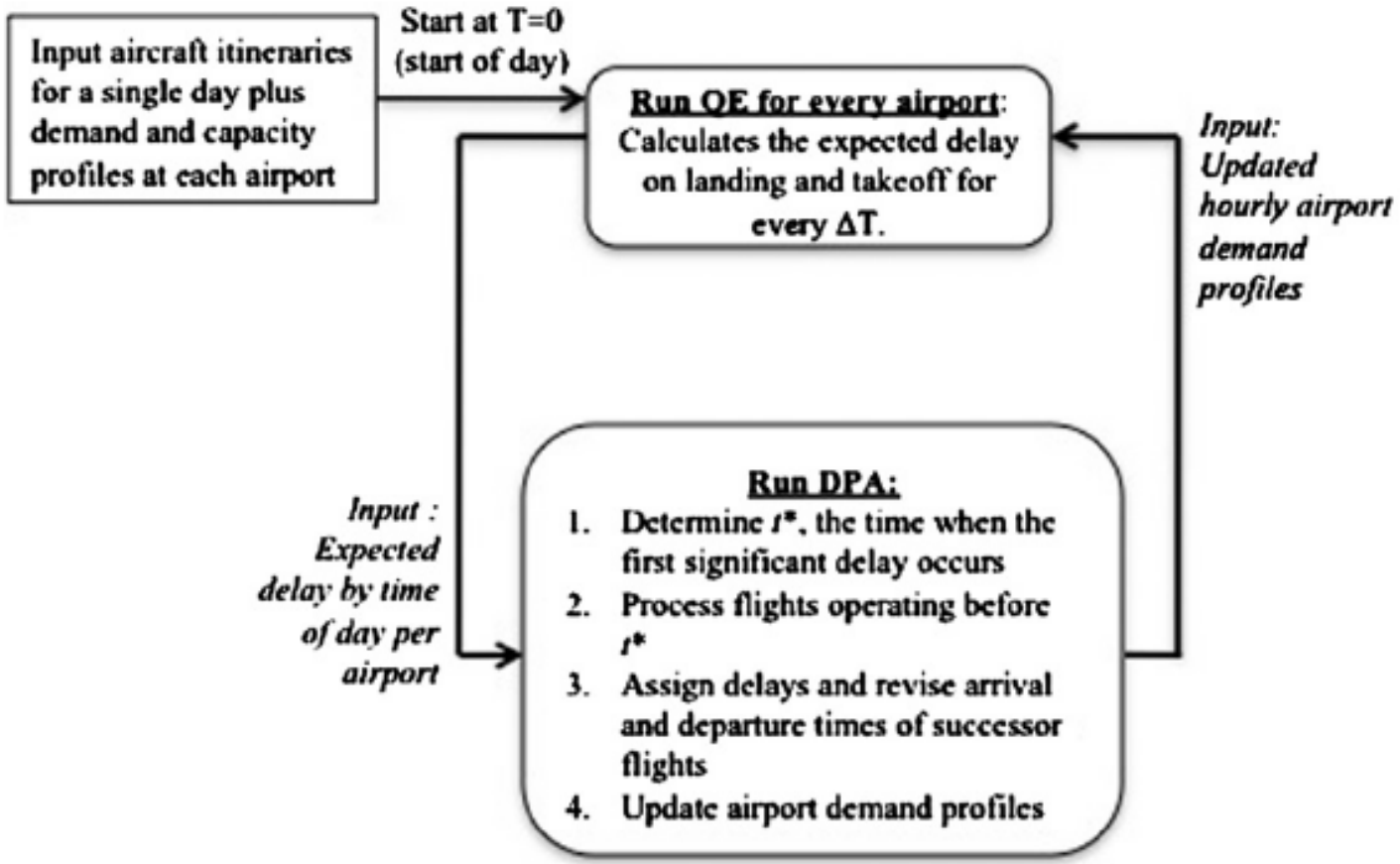




- **Reactionary delays are**
  - 50% of delays for low-cost carriers
  - 40% of delays for hub-and-spoke carriers

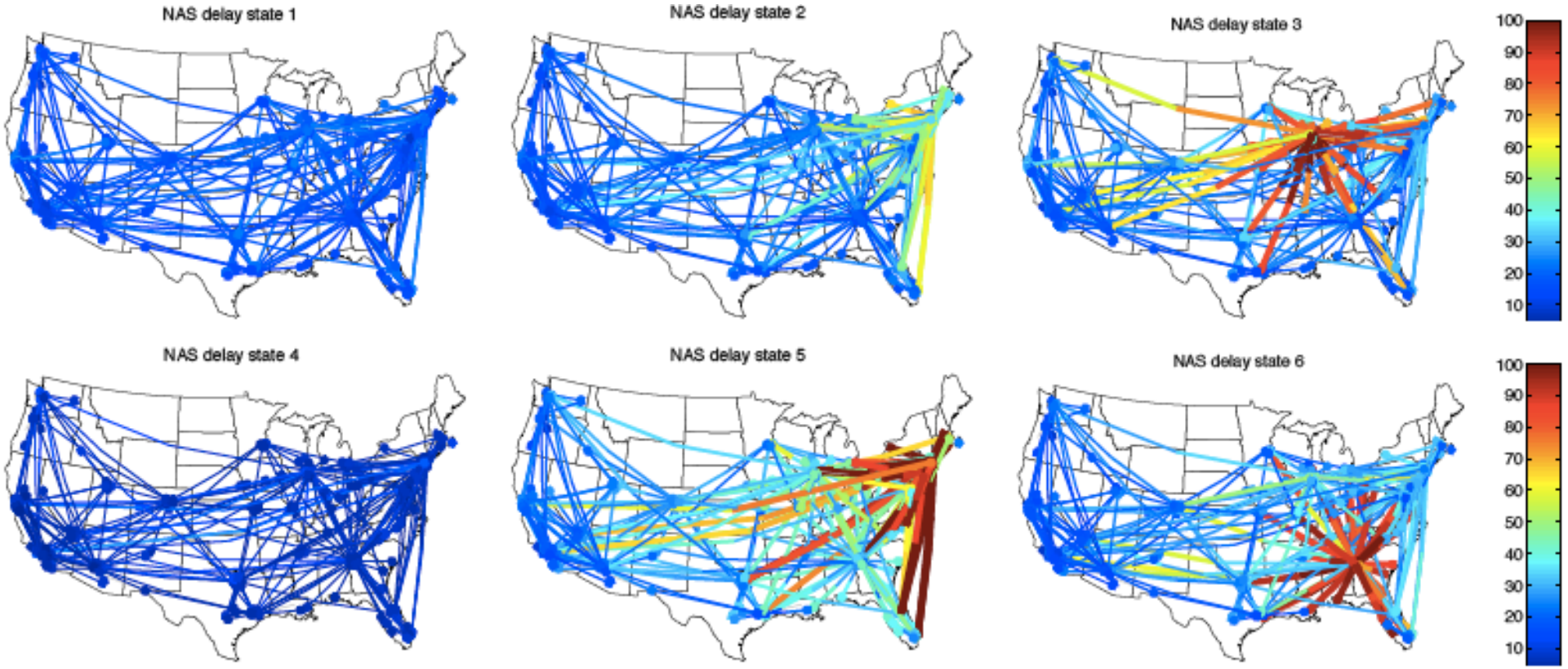
Queuing network models

- **Study by Pyrgiotis, Malone and Odoni (2013)**
  - Airports are nodes of queuing network
  - Models both local congestion impacts and delay propagation
  - Good qualitative match to data



Data-driven estimation of delay propagation

- **Study by Rebollo and Balakrishnan (2014)**
  - Identifies characteristic NAS "delay states"
  - Tries to predict future delays

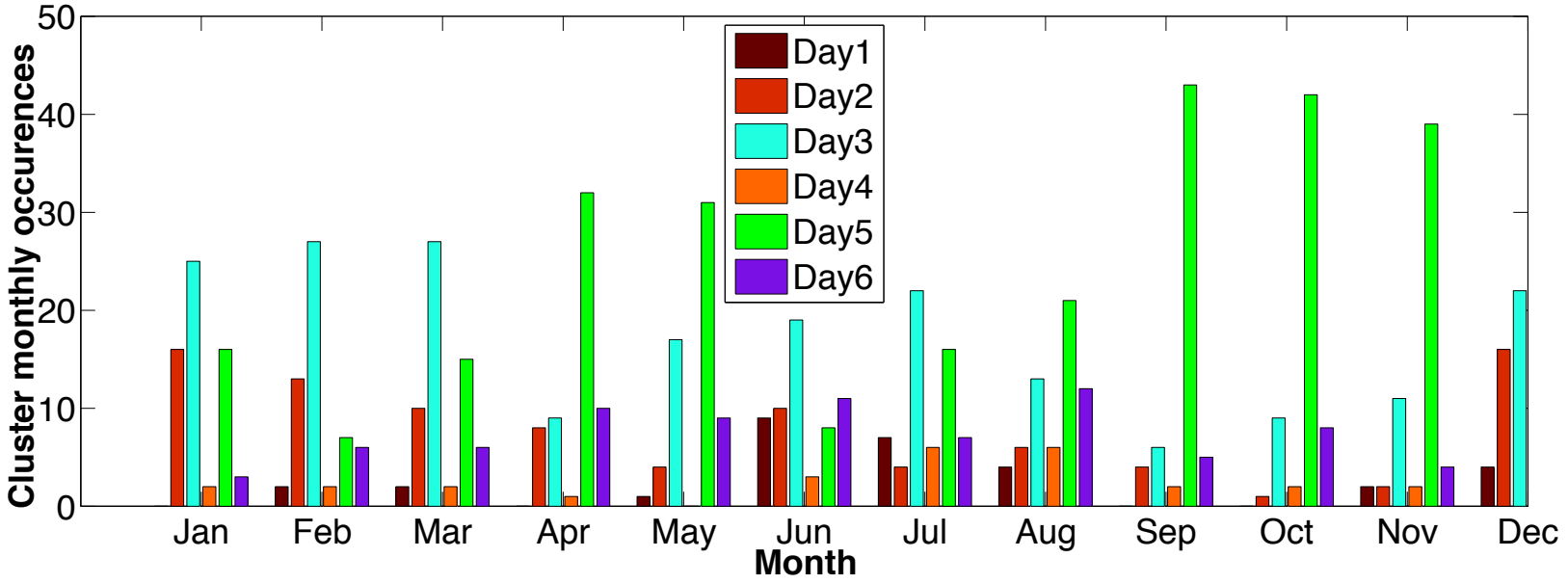


Centroids of NAS delay states.
Color represents median link departure delay over 2-hr time-window

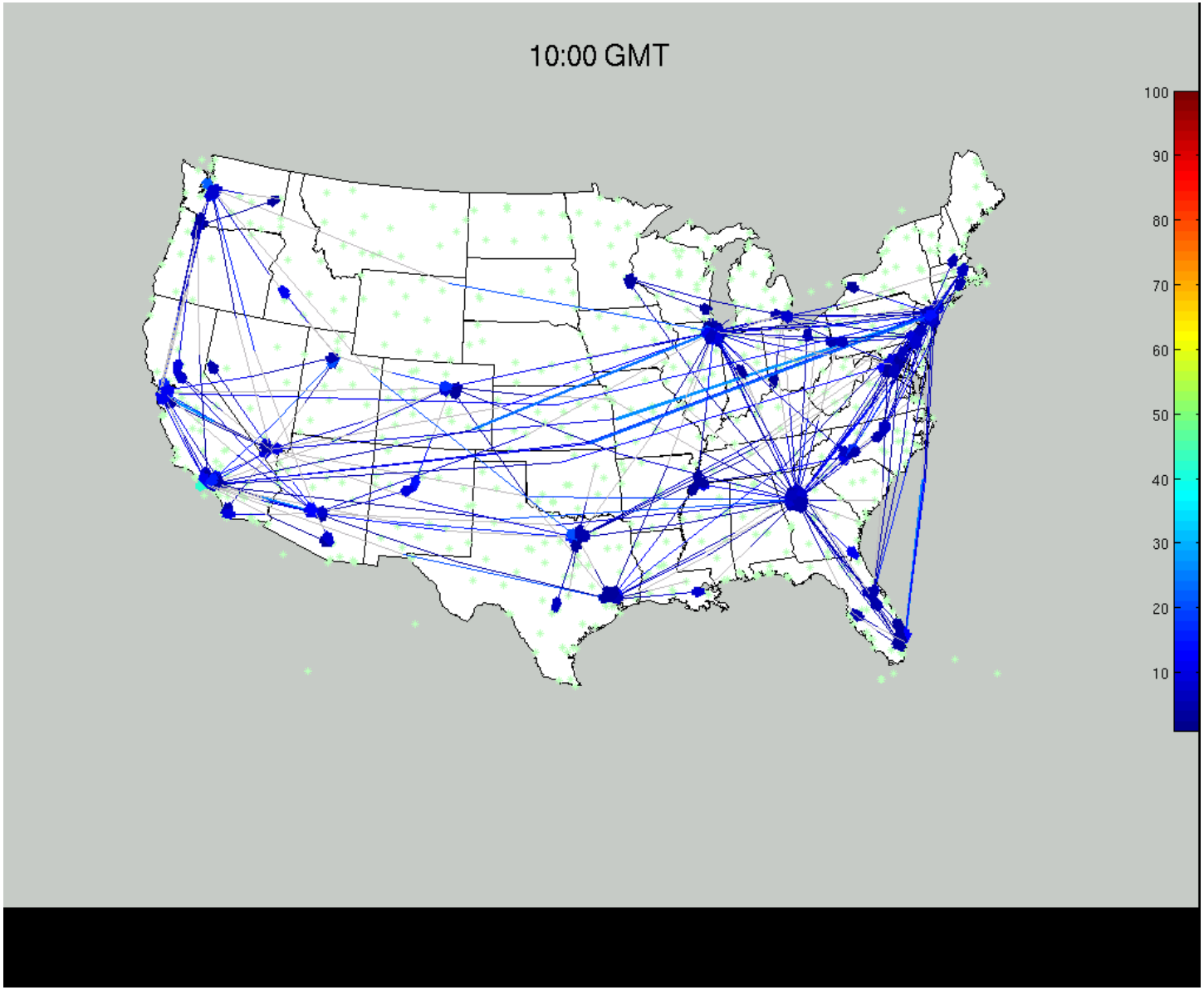
Characteristic types of NAS delay days

- **Delays:** High (90 min), med-high (60 min), medium (20 min), low (5 min)

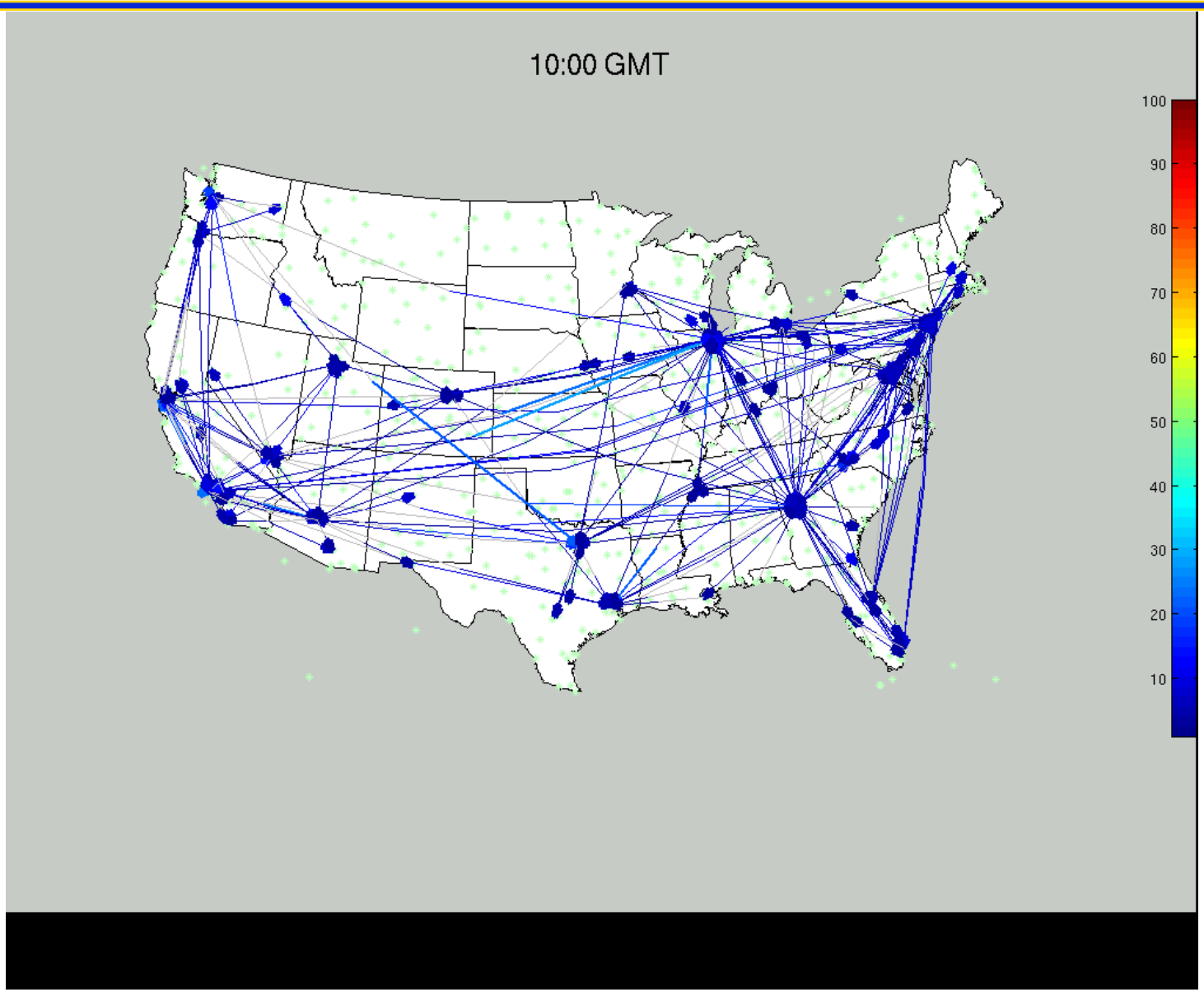
Centroids	Avg. delay (min)	Qualitative Description
Day 1	29	NYC very high, ATL, ORD high delay
Day 2	22	ORD high, NYC medium high delay
Day 3	15	NYC, ORD medium delay
Day 4	21	ATL high, NYC, ORD medium high delay
Day 5	9	Low NAS delay
Day 6	19	NYC high, ATL, ORD medium delay



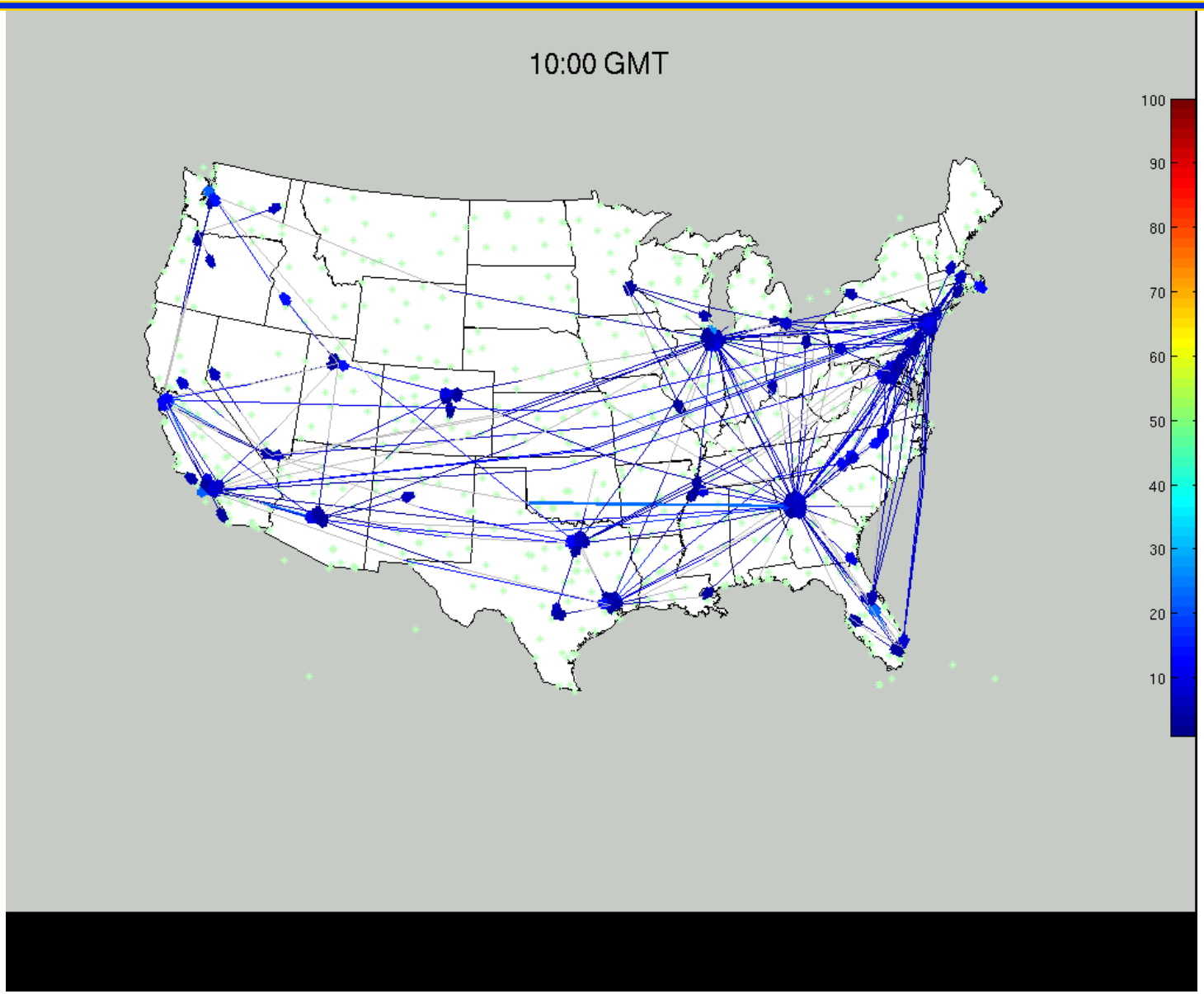
Day Type 1: NYC v. high, ATL, ORD high delays



Day Type 2: ORD high, NYC medium-high delays



Day Type 4: ATL high; NYC, ORD med-high delays



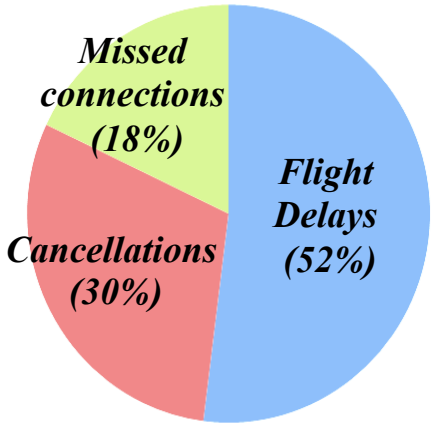
Passenger delays vs. flight delays

- **Flight delays don't present the complete picture on the impact on passengers**
  - Flight cancellations and missed connections
  - Re-accommodation is difficult if load factors are high

- **Data on passenger delays is sparse, making even the estimation of delays difficult**

Domestic passenger delays in the US

- **Study by Barnhart, Fearing and Vaze (2014)**
- **Estimated passenger delays in 2007: 244.5 million hours**
- **Delays by category:**



- **Average flight delay in 2007: 15.3 min**
- **Average passenger delay in 2007: 30 min**
- **Note that average passenger delay is nearly double average flight delay**