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Institute for Aviation  
and the Environment 

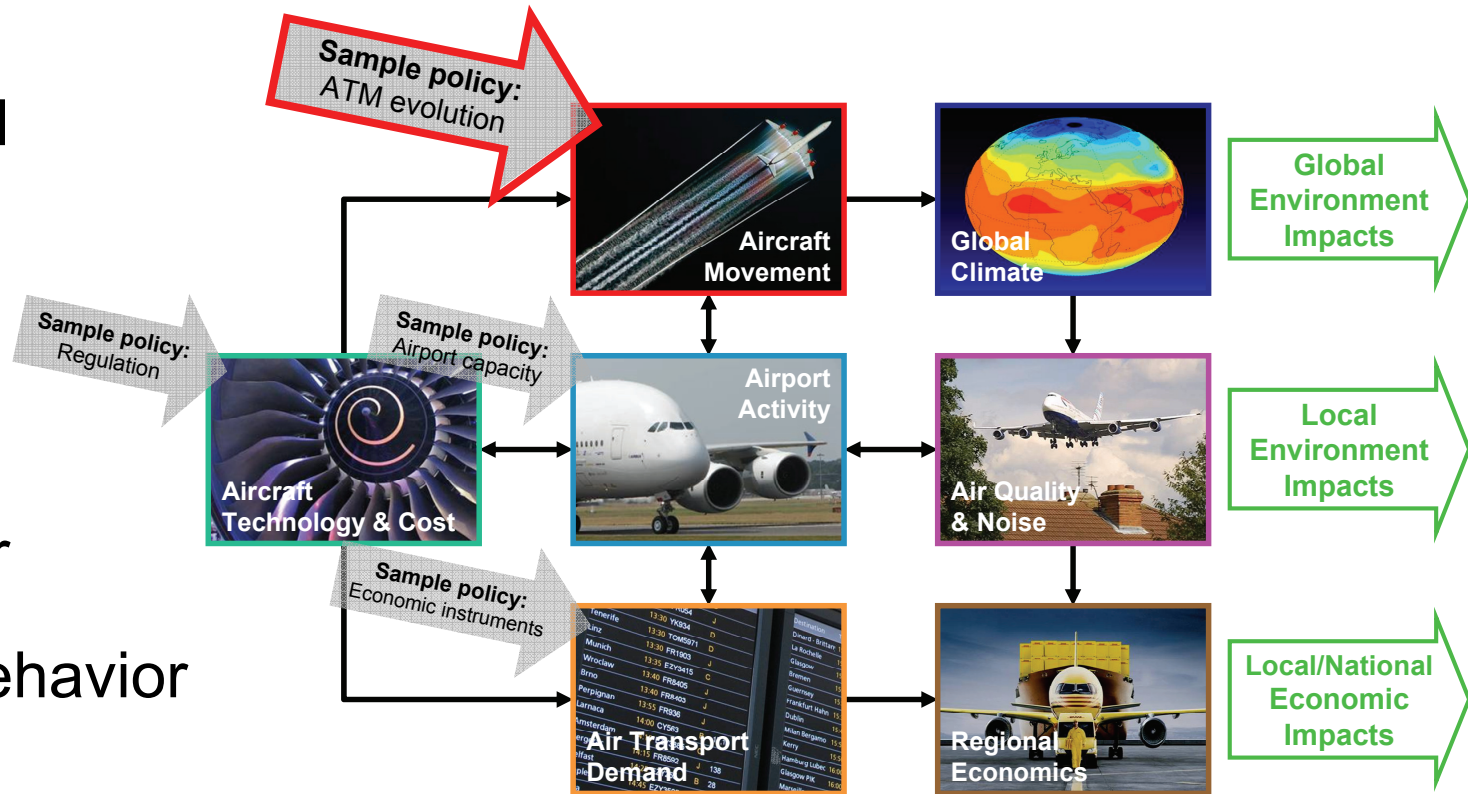
# **Analysis of Lateral Flight Inefficiency in Global Air Traffic Management**

**Tom G. Reynolds**



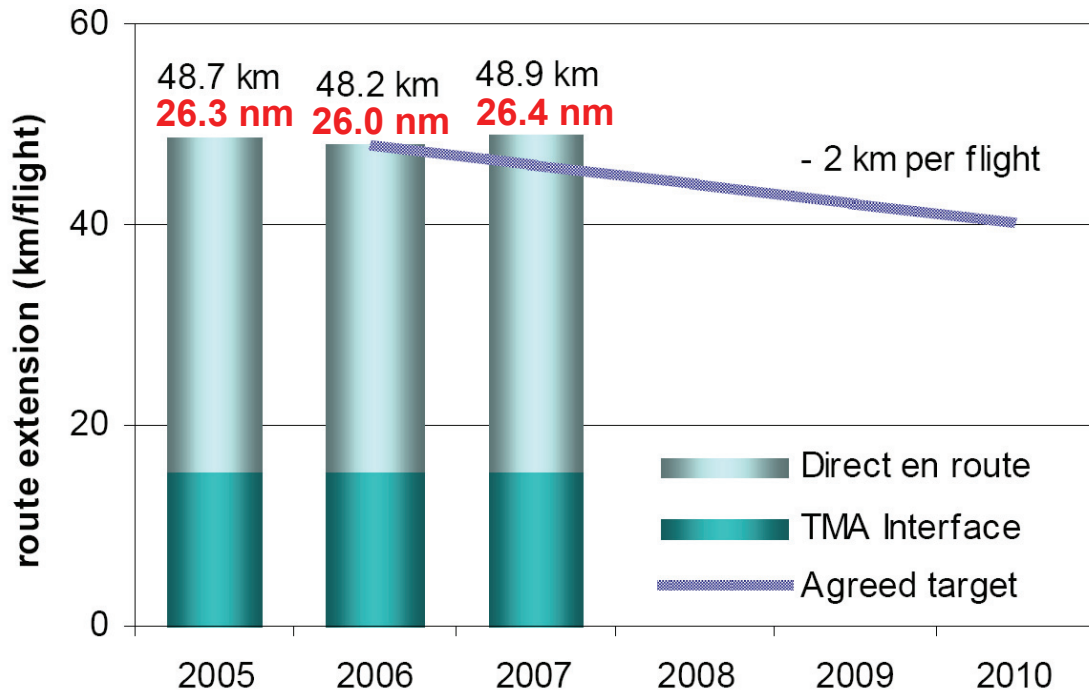
8<sup>th</sup> AIAA Aviation Technology, Integration and Operations Conference  
26<sup>th</sup> Congress of the International Council of Aeronautical Sciences  
Anchorage, Alaska, USA, 14-19 September 2008

- Aviation Integrated Modelling (AIM) research project taking holistic view of air transport system behavior



- Need to understand environmental performance of ATM
  - Forecast air traffic growth
  - New aircraft/engine technology turnover slow
  - ATM affects *all* aircraft in system

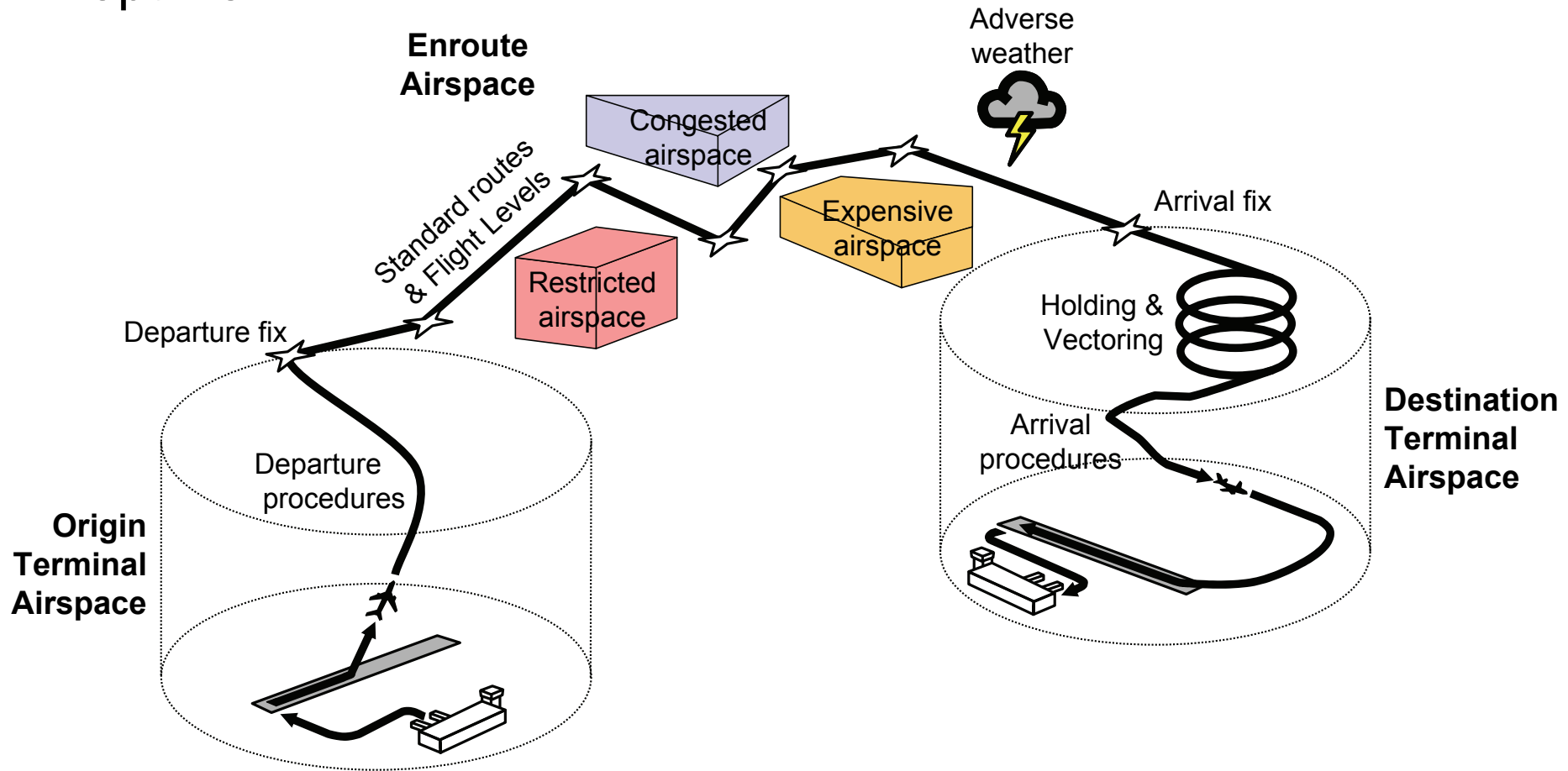
- Concept commonly used to identify ATM performance
  - Quantifying difference between “ideal” and “actual” performance
  - Focus has been on average route extension over great circle

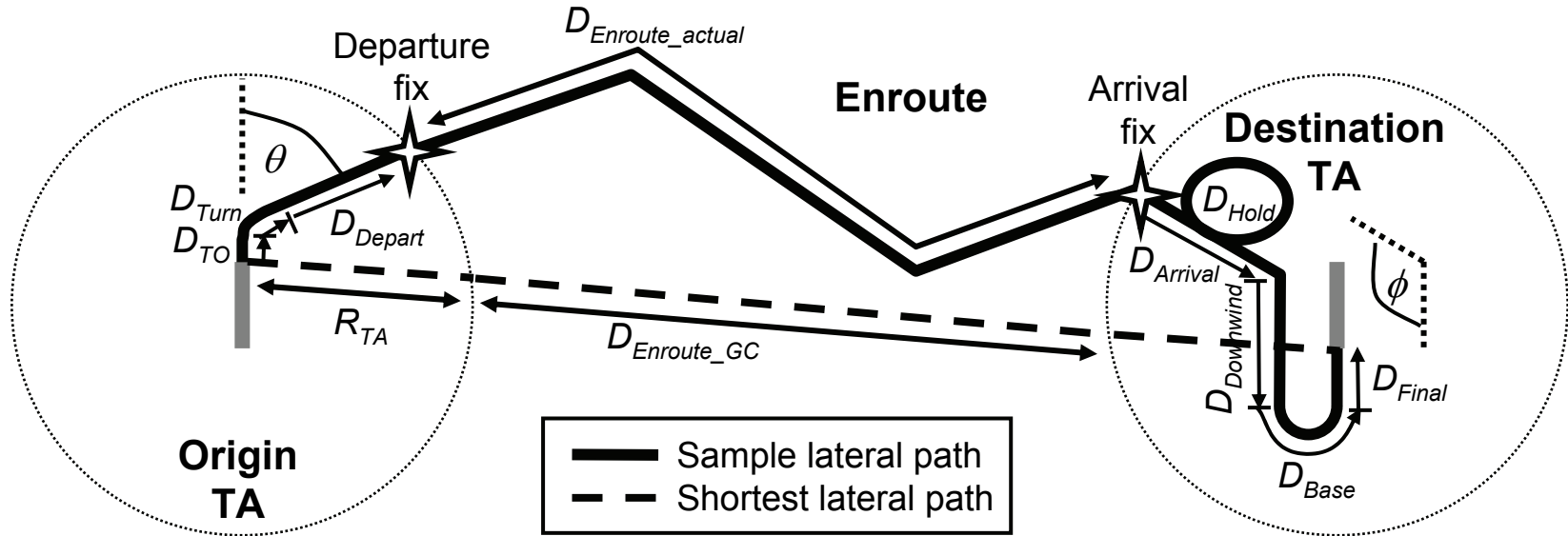


Source: Eurocontrol Performance Review Report 2007: An Assessment of Air Traffic Management in Europe, May 2008

- Need to expand understanding:
  - Inefficiency in different flight phases and causes
  - Relative performance of ATM in different geographic regions
  - How to improve future ATM performance
  
- Methodology used:
  1. Identify sources of flight inefficiency in different phases
  2. Create models of *route extension* in different phases
  3. Use flight data to characterise:
    - Current route extension in different flight phases
    - Current route extension in different geographic regions
    - Relative importance of different sources of inefficiency
  4. Use results to inform priorities for future ATM evolution strategies

- Factors that make aircraft fly a trajectory different from its 4D optimal:



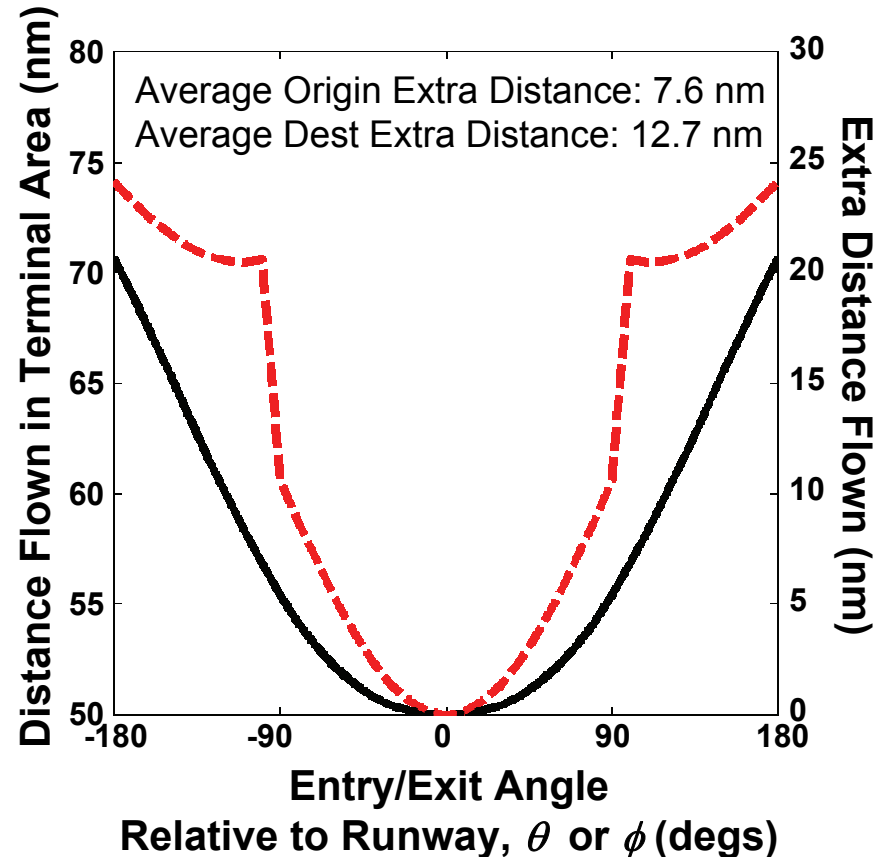
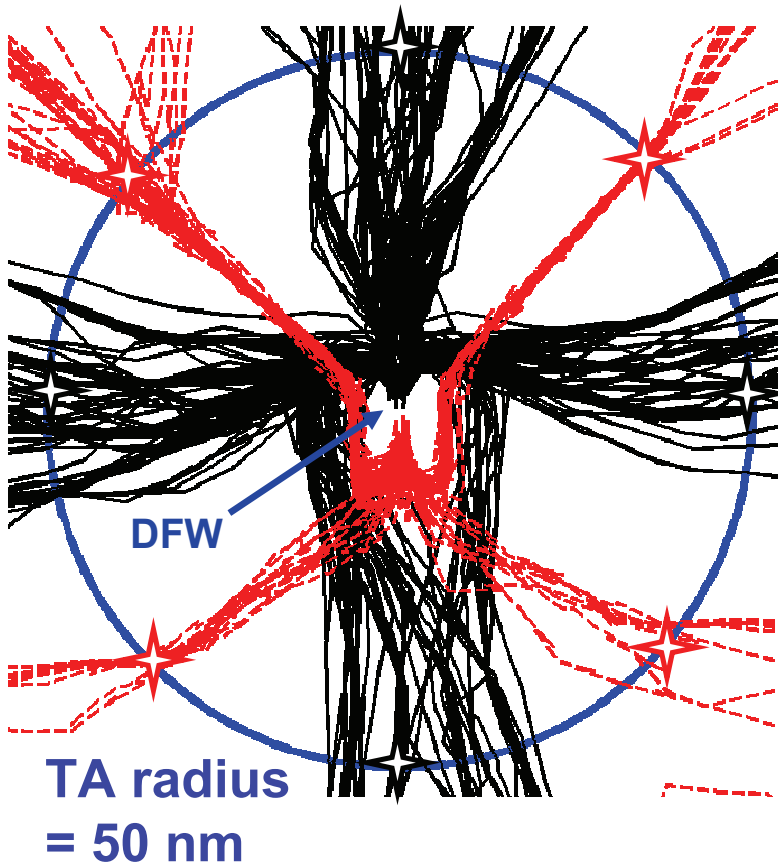


$$XD_{OriginTA} = (D_{TO} + D_{Turn} + D_{Deport}) - R_{TA}$$

$$XD_{Enroute} = D_{Enroute\_actual} - D_{Enroute\_GC}$$

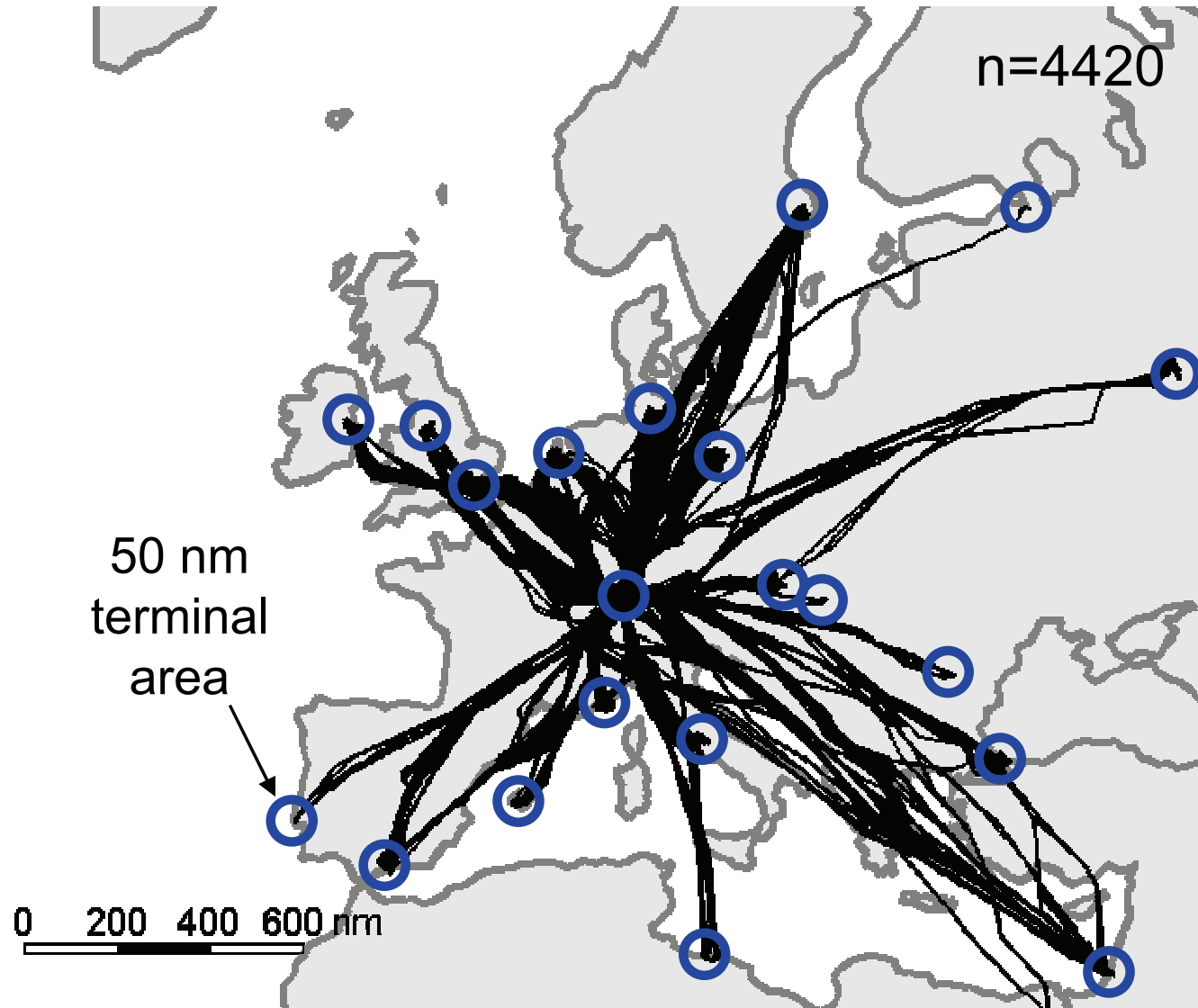
$$XD_{DestTA} = (D_{Arrival} + D_{Hold} + D_{Downwind} + D_{Base} + D_{Final}) - R_{TA}$$

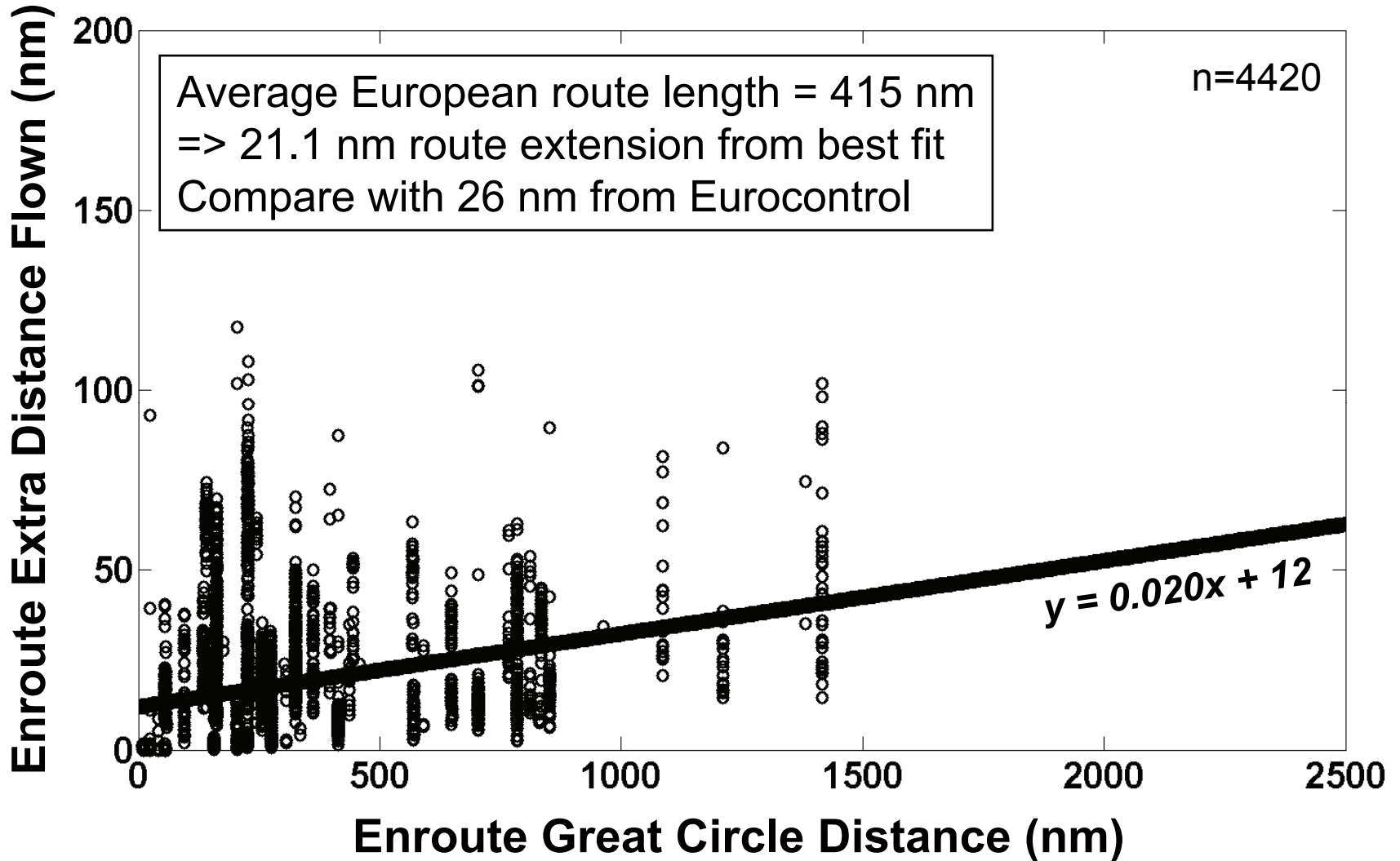
- Some route extension expected in terminal areas due to standard departure/arrival procedures



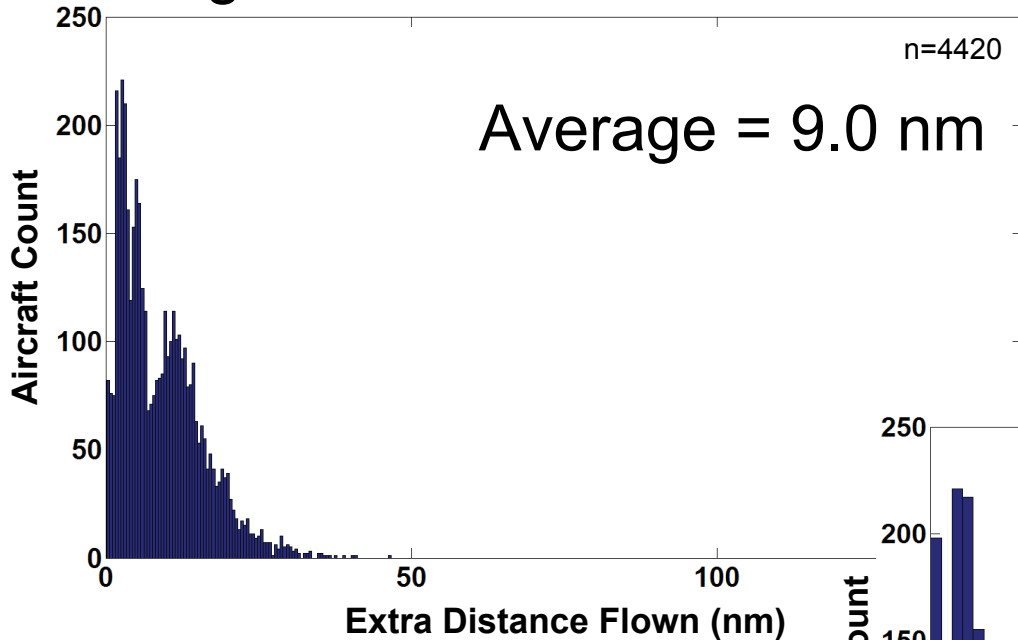
# Results: Europe

- Flight data recorder information from European-based airline during early 2008
- A319, A320, A321 and ARJ100 aircraft



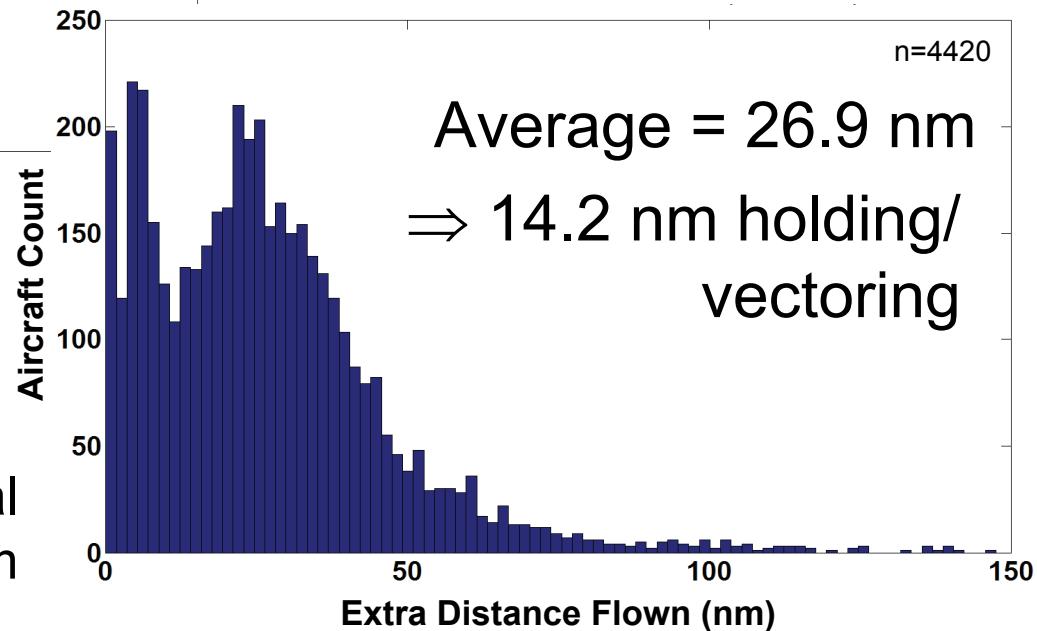


## Origin TA



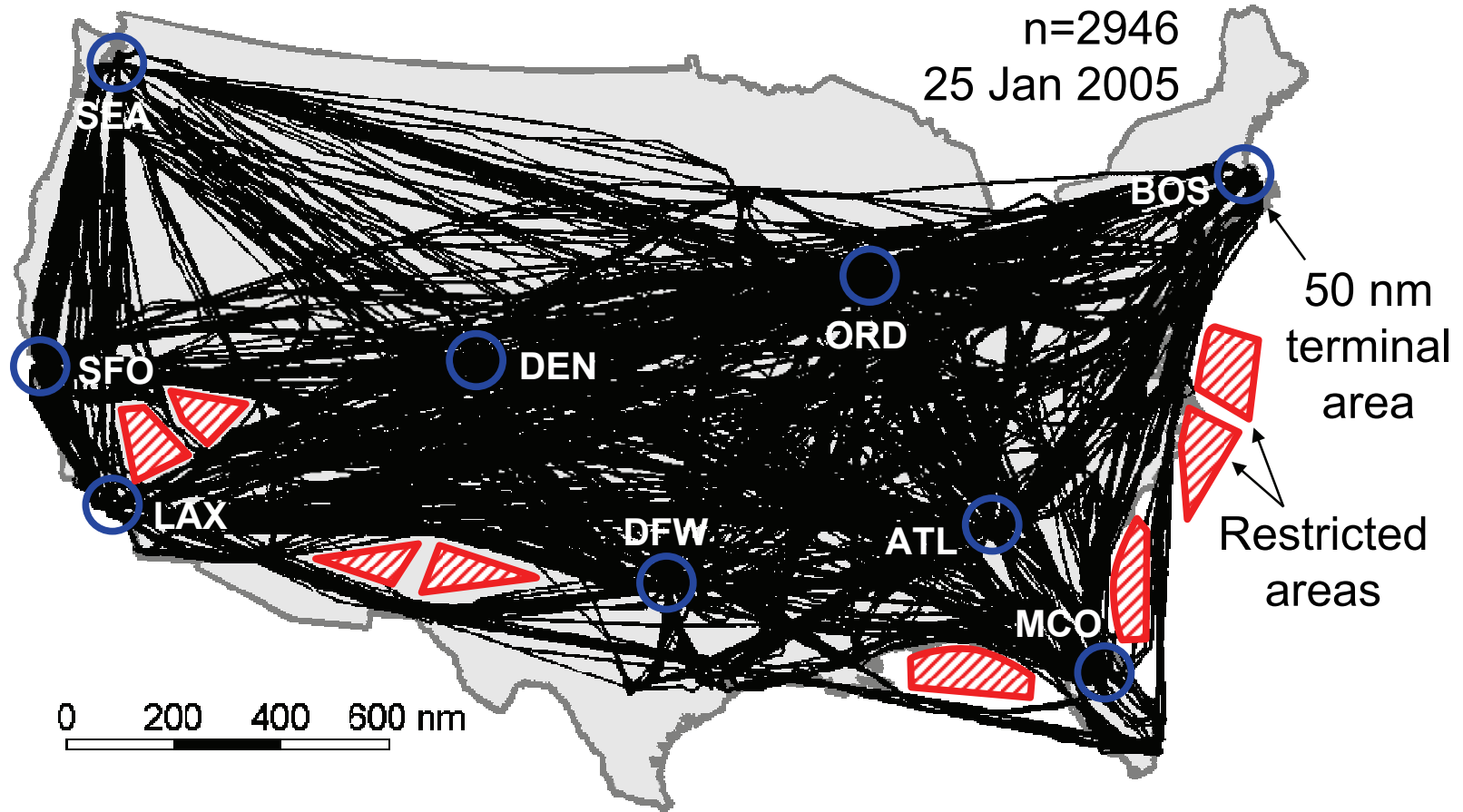
Compare to standard departure  
extra distance of 7.6 nm

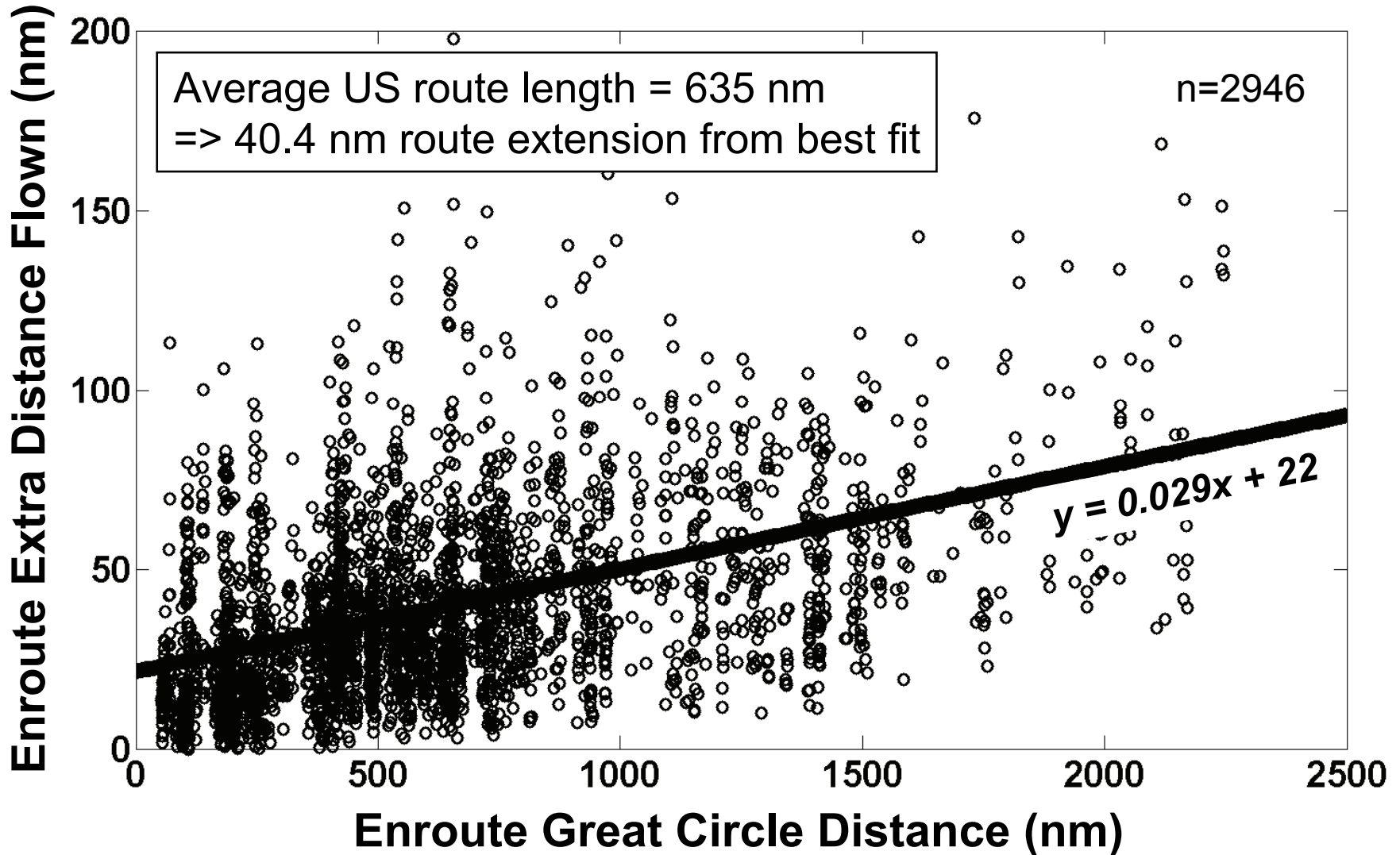
## Destination TA



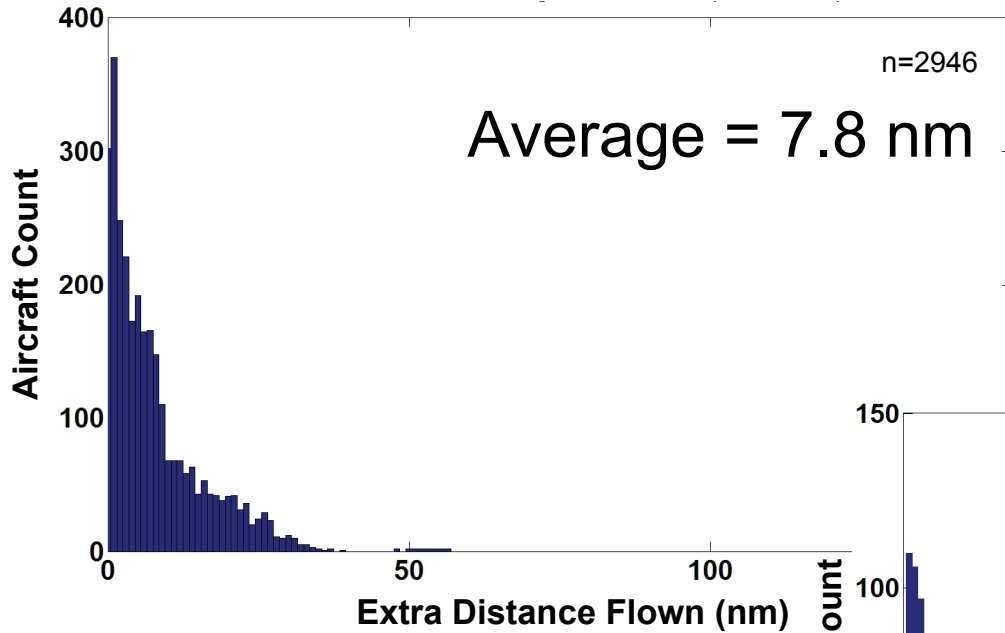
Compare to standard arrival  
extra distance of 12.7 nm

- ETMS data from 4 representative weeks in 2005



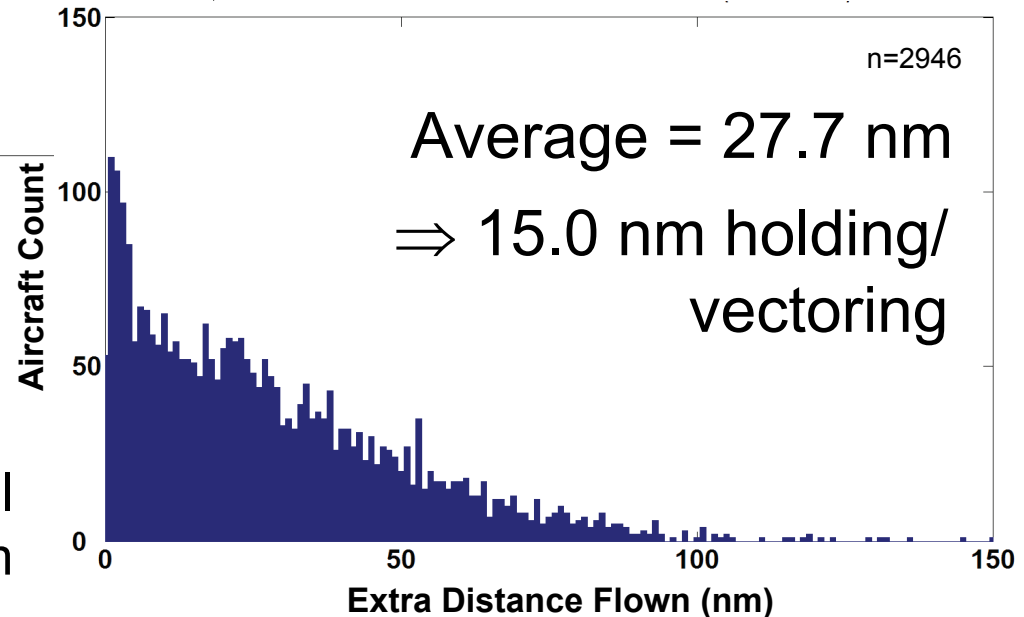


## Origin TA



Compare to standard departure  
extra distance of 7.6 nm

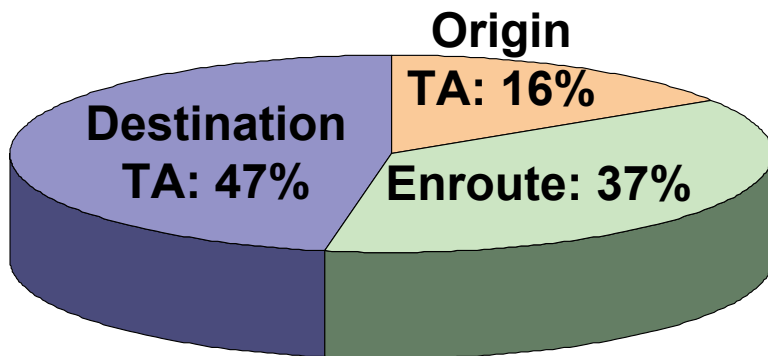
## Destination TA



Compare to standard arrival  
extra distance of 12.7 nm

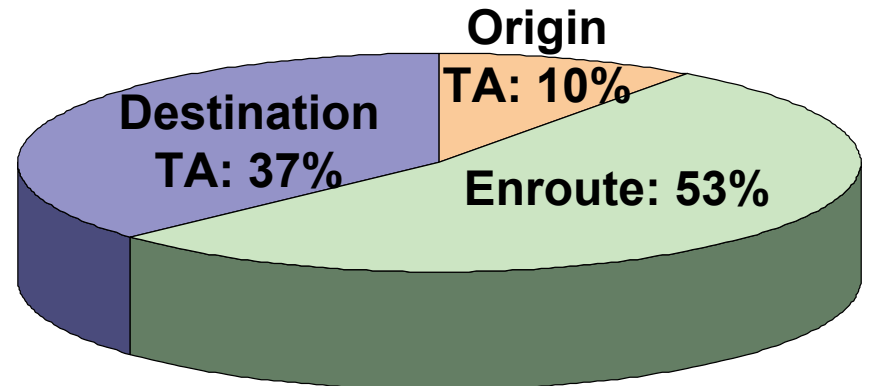
## Europe intracontinental

Average route (415 nm)  
extra distance flown:  
57.0 nm (14%)

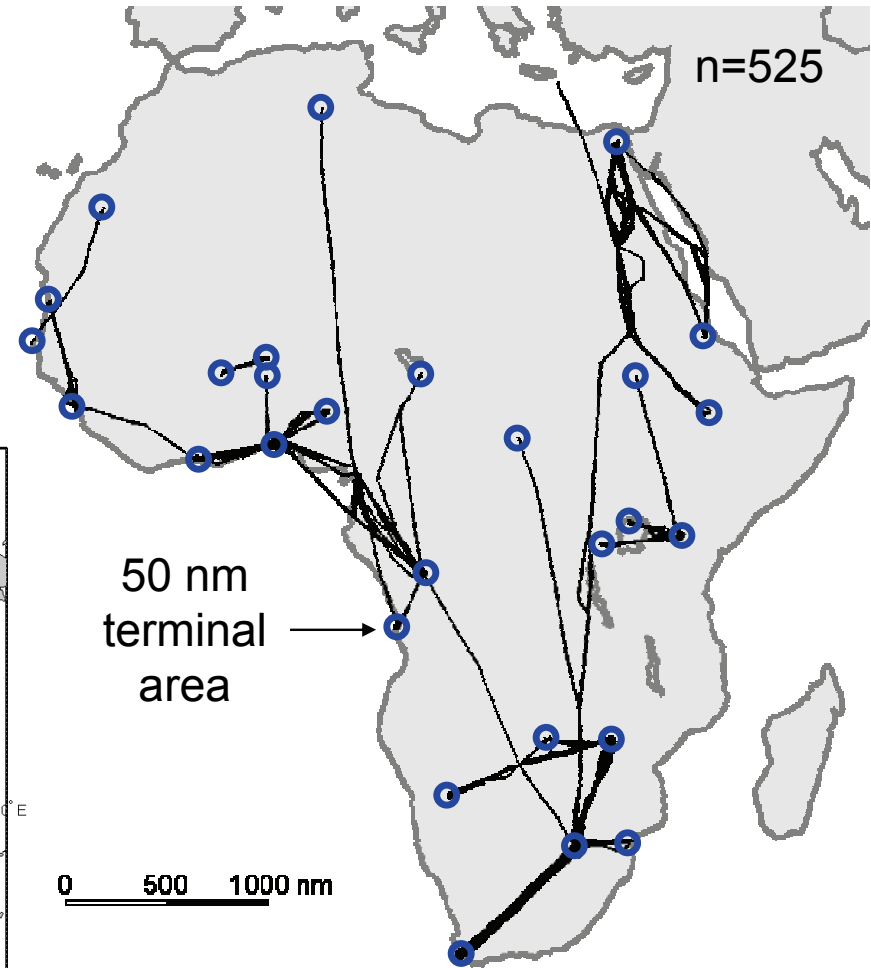
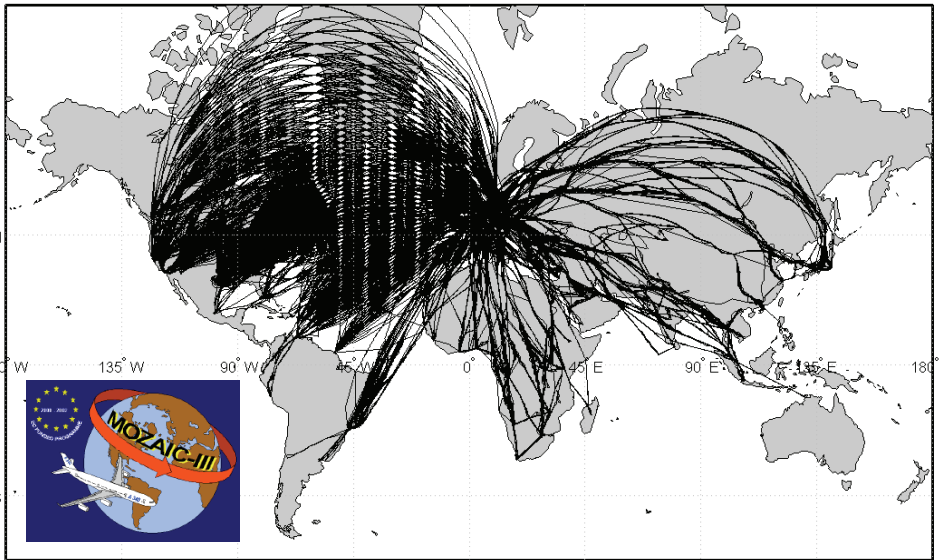


## USA intracontinental

Average route (635 nm)  
extra distance flown:  
75.9 nm (12%)

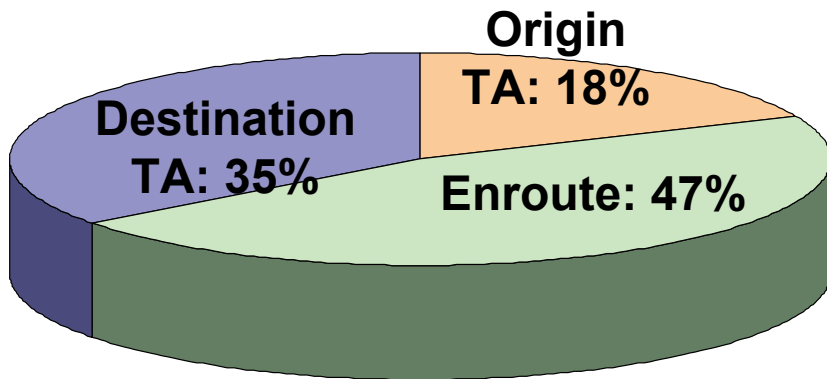


- Data from MOZAIC atmospheric observation aircraft
- 5 European and African-based A340s during revenue service 1996-2006

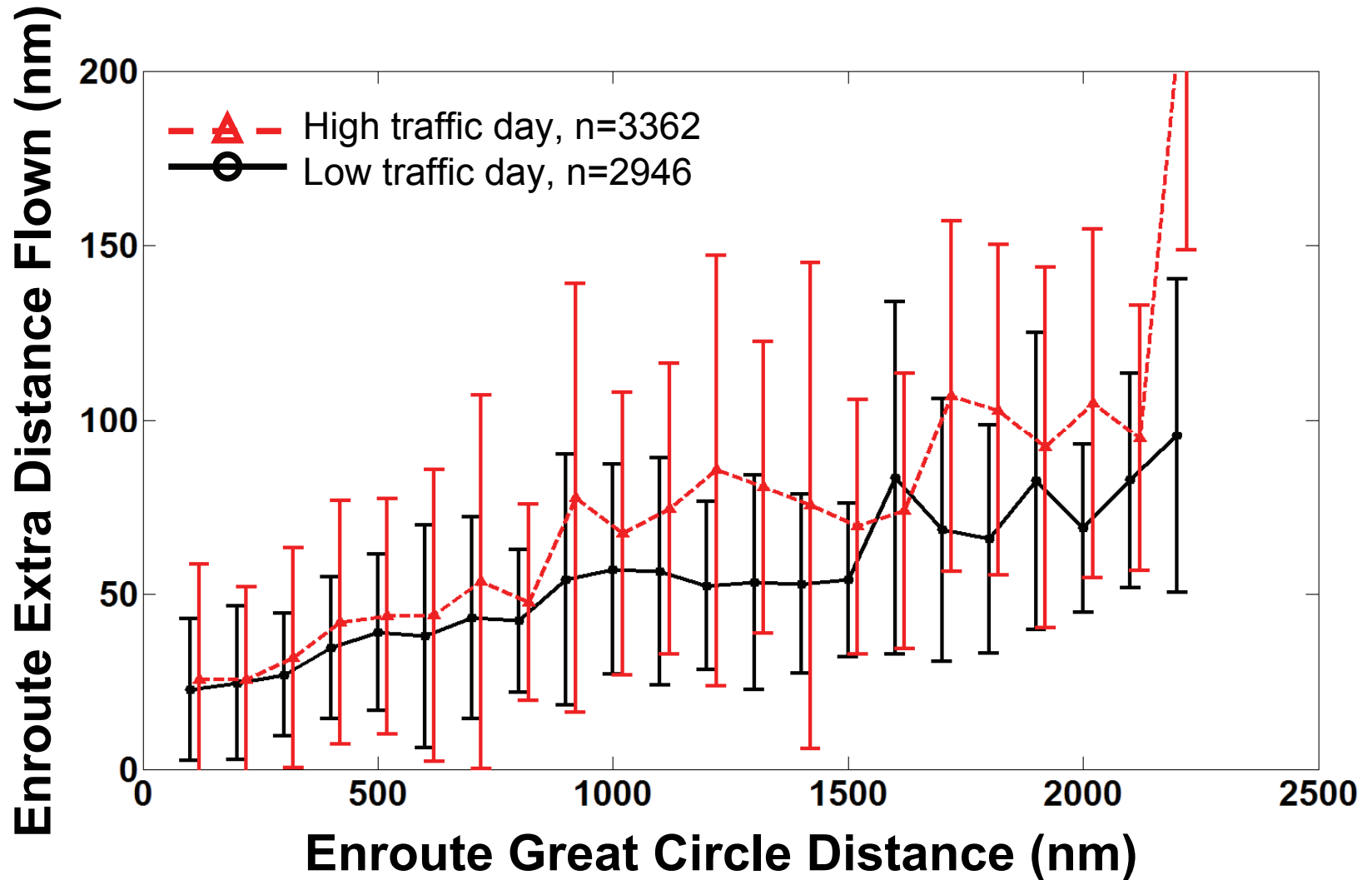


## Africa intracontinental

Average route (489 nm)  
extra distance flown:  
40.5 nm (8%)

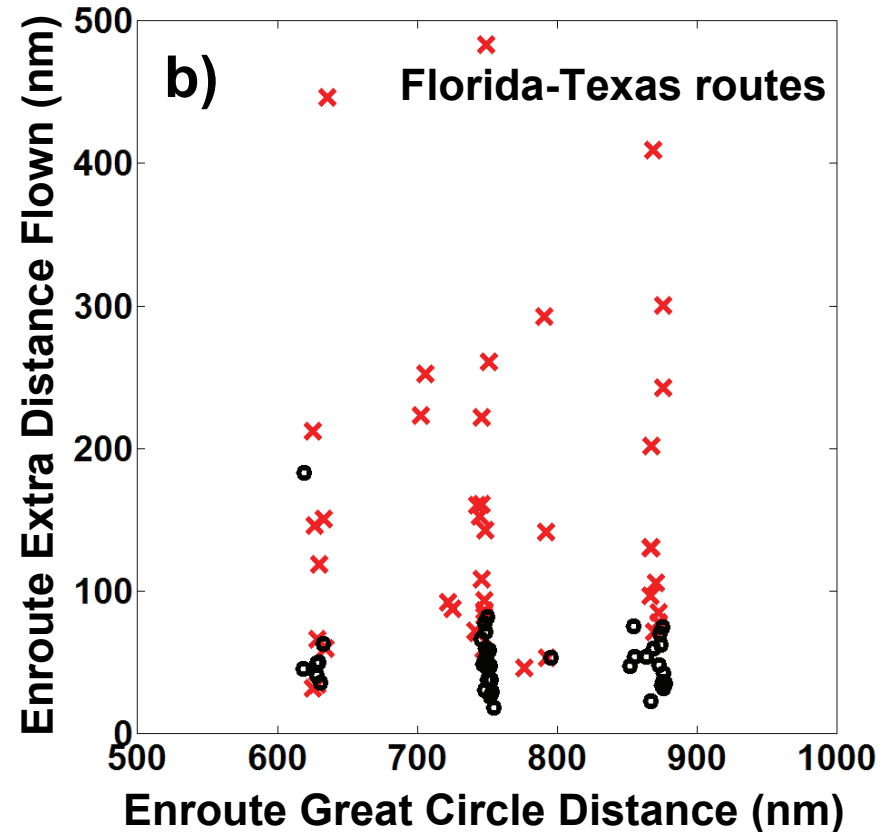
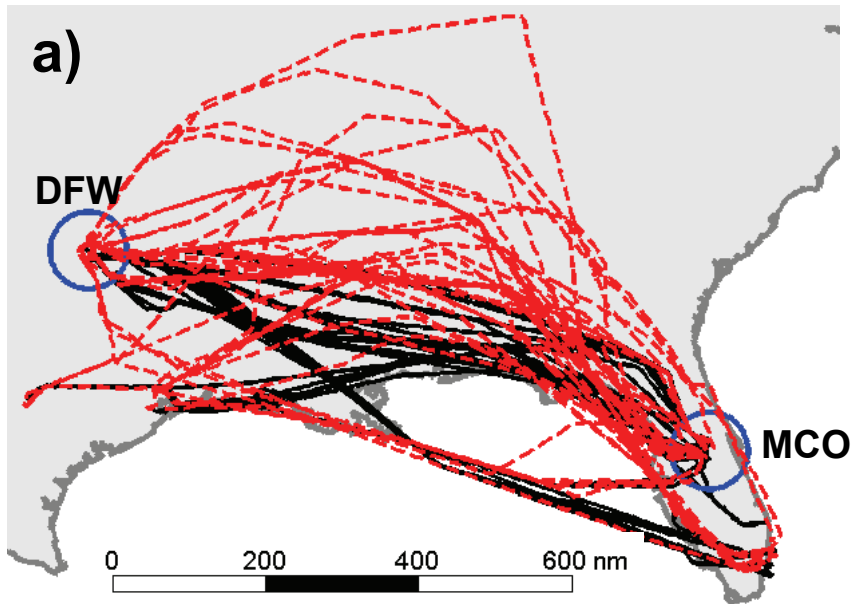


- Airport capacities and traffic levels an order of magnitude lower in Africa compared to US/Europe
- ICAO forecast growth to 2050 greater in Africa
- Relationship between demand, airport capacity and inefficiency needs further study

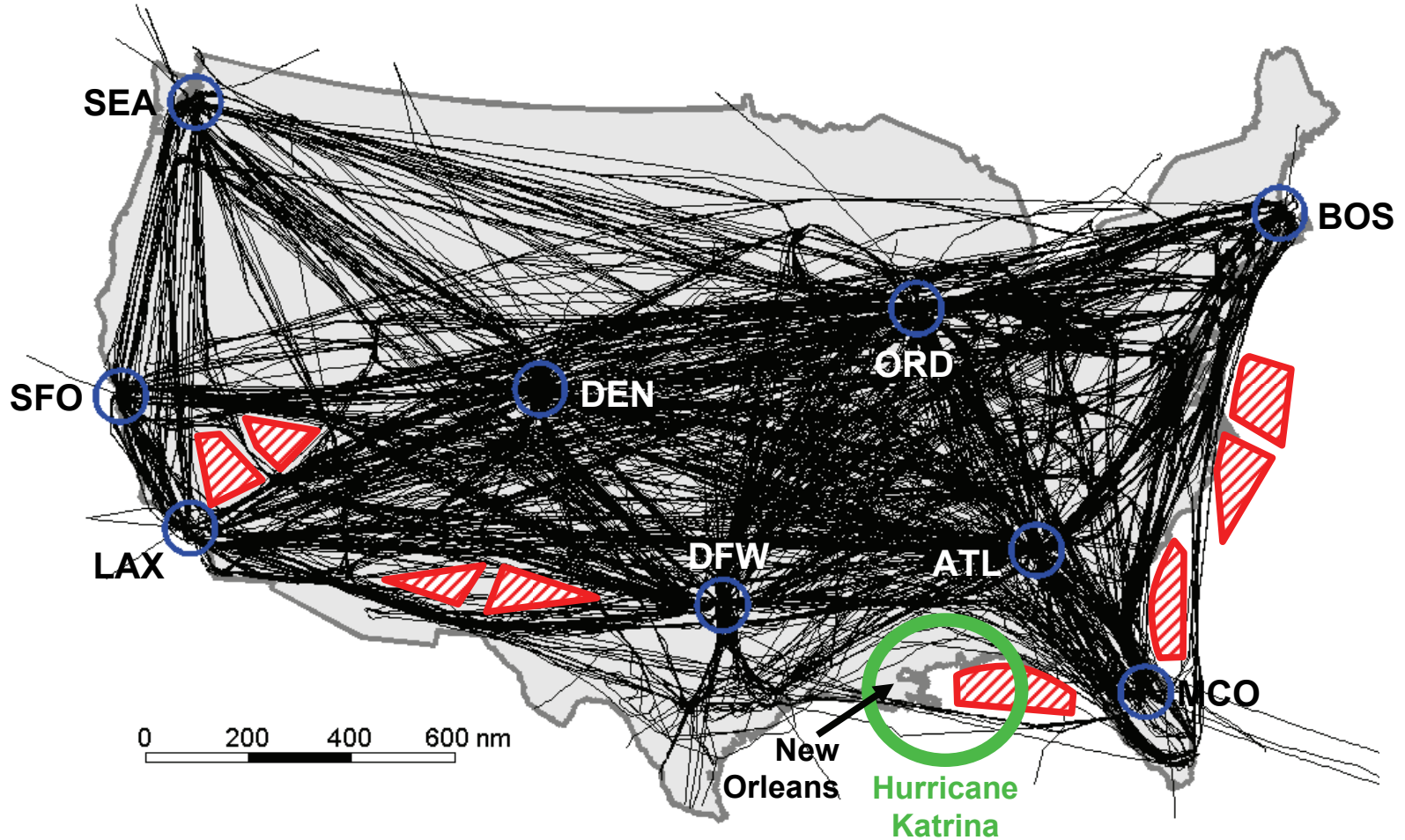


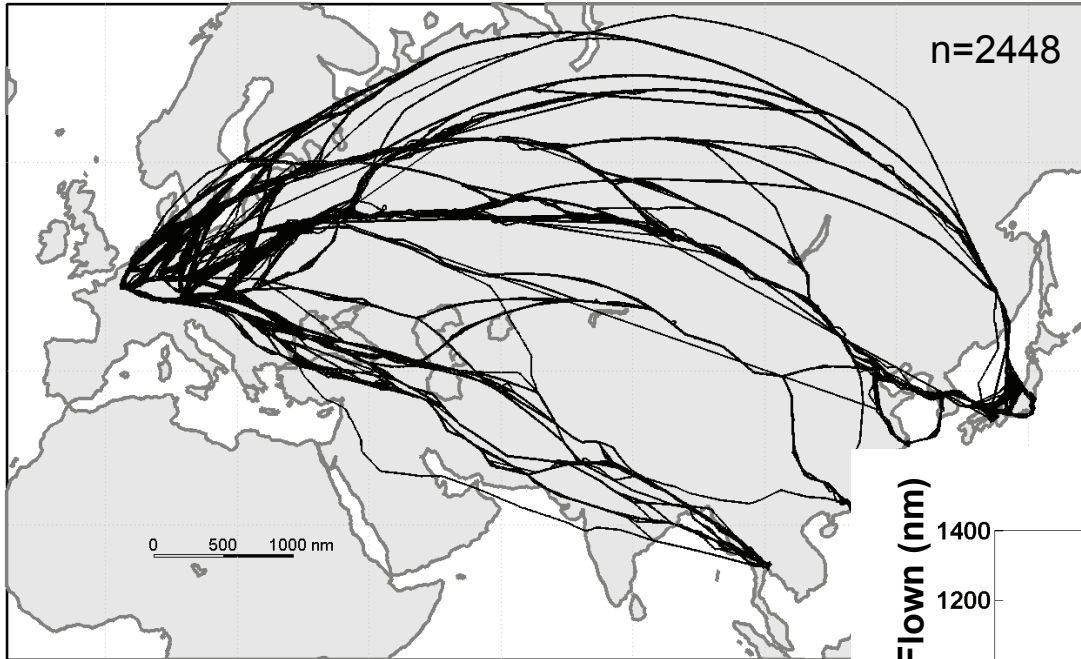
- Can have high local impact...

○ — 25 Jan 2005 (“normal” day), n= 46  
 × - - - 29 Aug 2005 (Hurricane Katrina), n=52



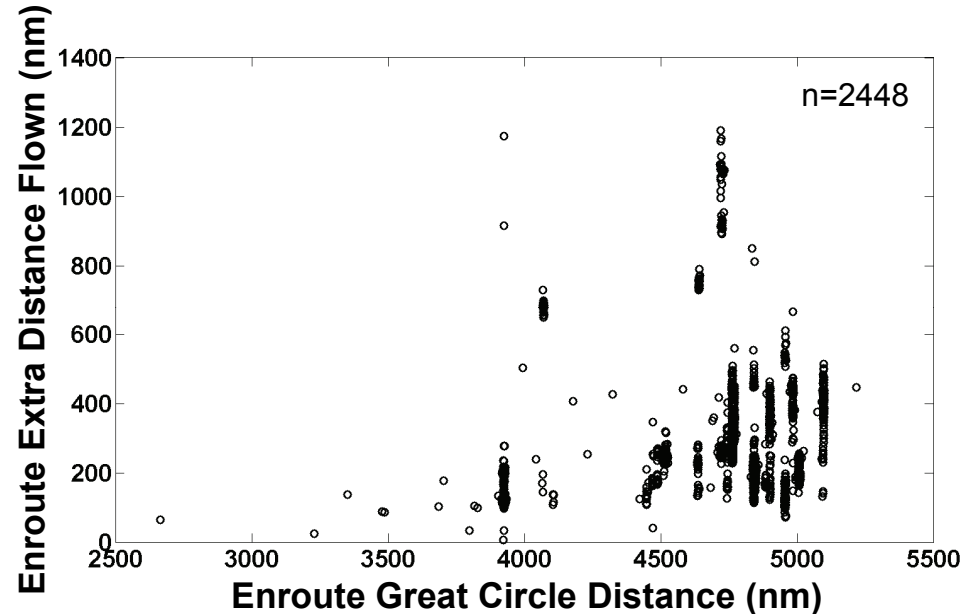
- ... but system-wide effects lower

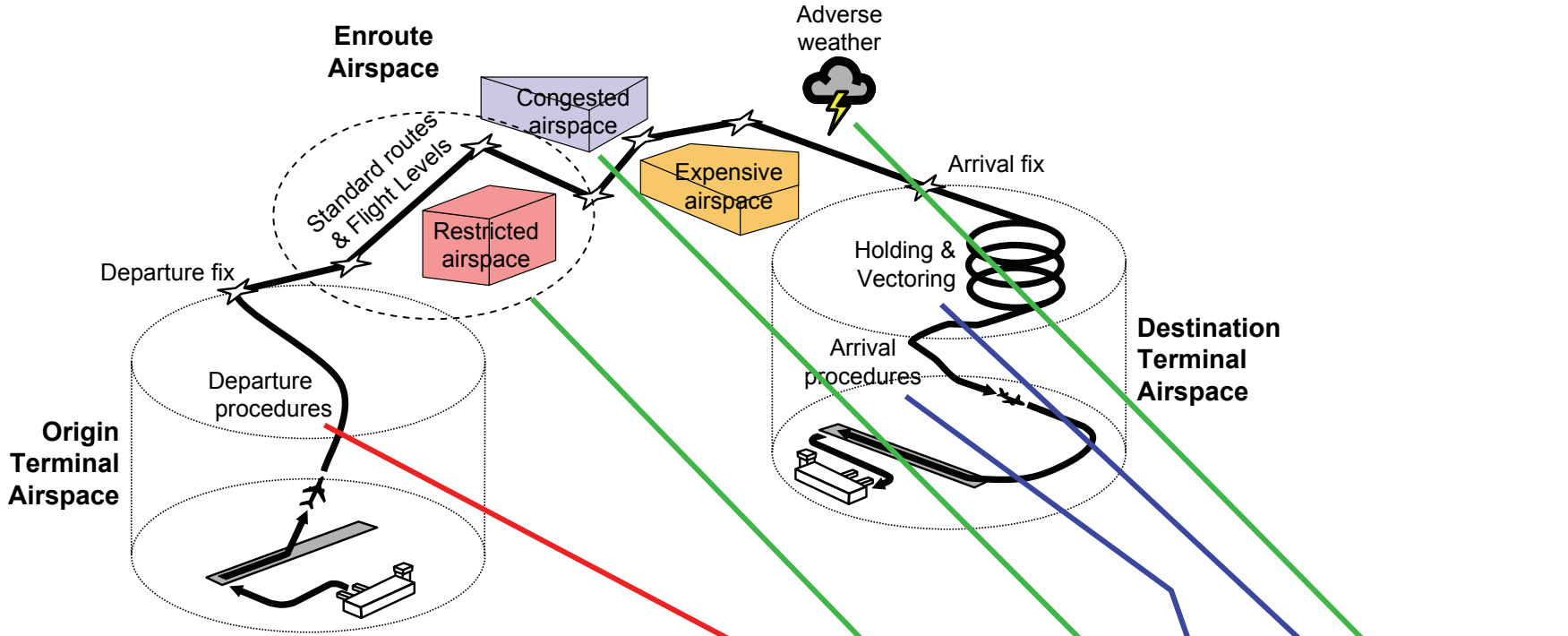




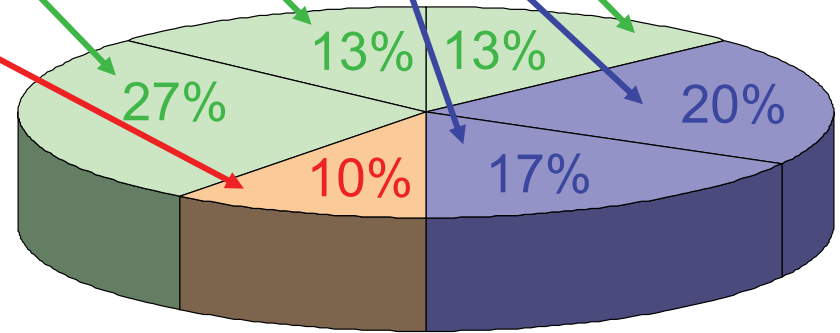
- High route flexibility in European airspace
- Limited number of international routes over Russia & China

- Causes extra enroute flight distances of up to 1200 nm



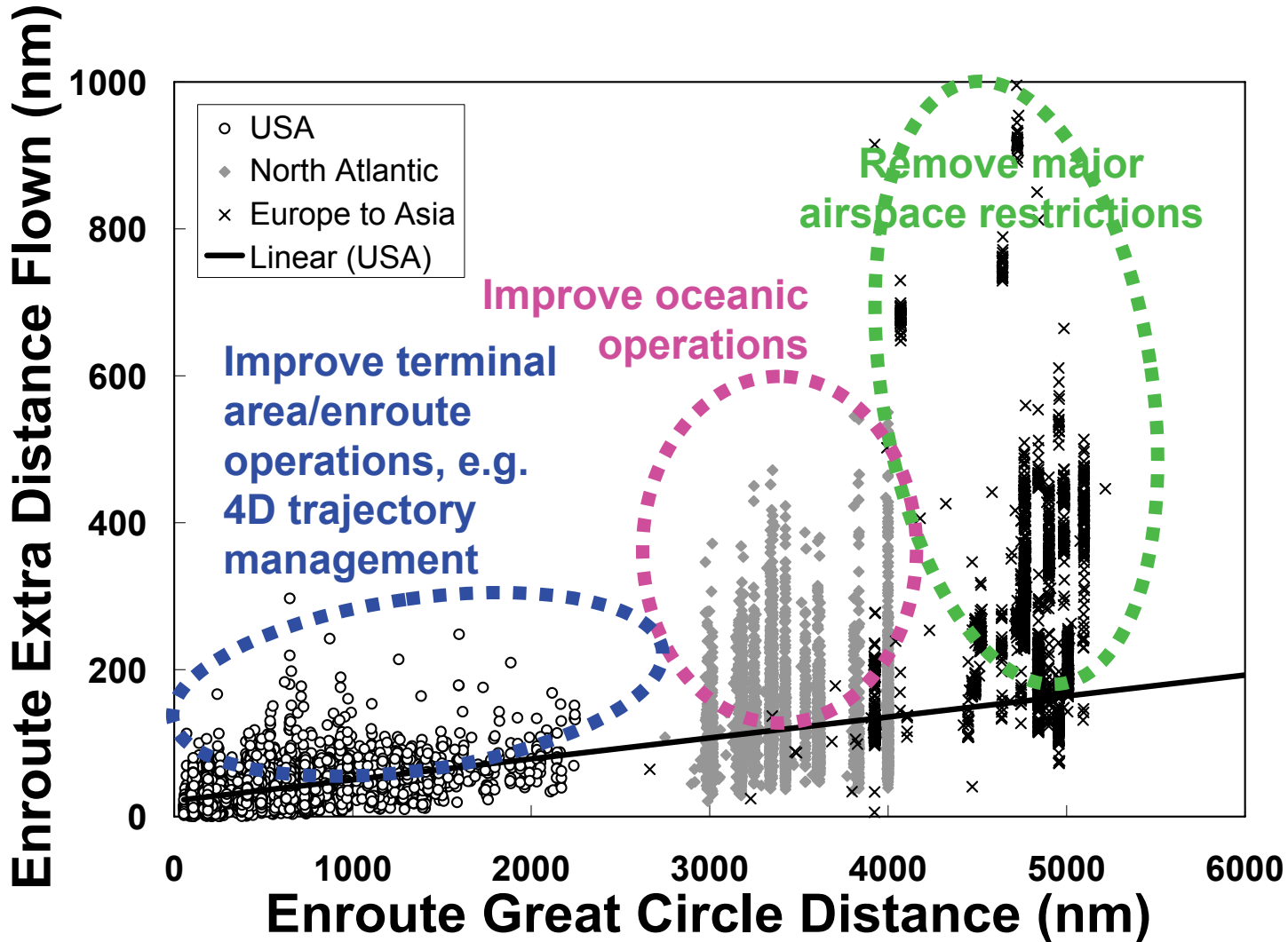


- What happens to pie size and components in future?
  - Traffic growth
  - Technology evolution
  - Procedural changes
  - Policy introduction



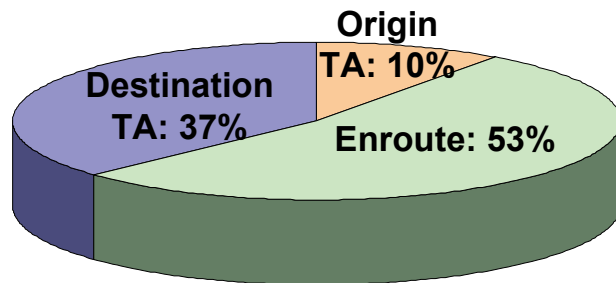
Typical values from US/Europe analysis

Inefficiency Source	Current US Contribution	Improvement Options
Standard routes & Restricted airspace	27%	“Free flight”/user-preferred trajectories/CNS upgrades
Arrival holding & vectoring	20%	4D trajectory management, tailored arrivals
Arrival procedures	17%	Separation minima reduction?
Congested airspace	13%	4D trajectory management
Adverse weather	13%	Better forecasting/adverse weather detection?
Departure procedures	10%	Separation minima reduction?



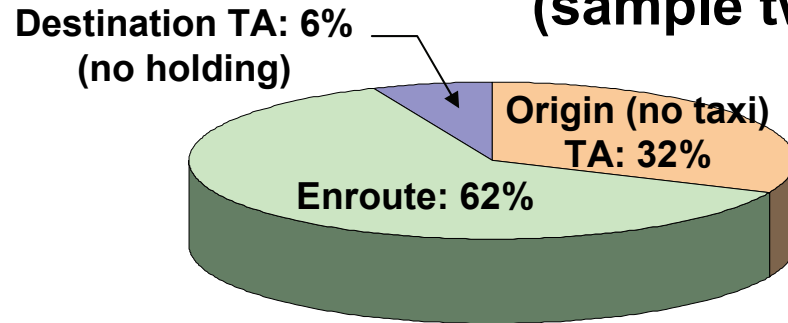
- ATM performance is important to assessment of environmental impacts of aviation
  - Flight inefficiency metrics quantify scope for improvement
- Extra distance flown metric presented
  - Importance of world region and flight phase
  - Relative importance of different inefficiency sources
- Consideration of enroute phase alone is insufficient
- Helps inform effects of future ATM system designs

## US Extra Distance Flown



## Fuel Burn Breakdown

(sample twin-jet)



- Redoing analysis using FUEL inefficiency metrics
  - Compare actual fuel burn to optimal fuel burn (FDR data)
  - More compatible with environmental performance
  - Optimal fuel burn from aircraft performance models
  - Collaborations underway with CANSO, Eurocontrol, NATS
  
- Examine relationship between demand, airport capacity and inefficiency more closely for ATM evolution scenarios

- Funding bodies:

 EPSRC

Engineering and Physical Sciences  
Research Council



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